BIOLOGY

A Textbook for Secondary Schools

BIOLOGY
A TEXTBOOK FOR SECONDARY SCHOOLS

Edited by
P. MAHESHWARI
and
MANOHAR LAL

SECTION 1
SOME BASIC FACTS ABOUT LIFE

NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

First edition	September	1964
Reprinted	July	1966
Reprinted	June	1967
Reprinted	September	1967

Price Rs. 2.25

Published by the Publication Unit, National Council of Educational Research and Training, B-31, Maharani Bagh, New Delhi-14 and printed at Shuchi Private Limited 18-A/12, Doriwalan, Rohtak Road, New Delhi-5

Foreword

FOR several years I have seriously felt the lack of good school and college textbooks on biology. Most of the existing books emphasize only the descriptive aspects of the subject, largely ignoring the newer and more fundamental concepts. This is, in part at least, responsible for adversely influencing the public image of biology and for relegating it to a subordinate position in the list of sciences. No thinking person can doubt that biology profoundly affects the life of all human beings and its study is one of the most essential requisites of every responsible and intelligent citizen. Further, the study of biology must begin right in the school as an integral part of any course in science instead of being postponed to the college or university stage. The pupil's choice of the subject of his future study is determined, to a large extent, by the courses he has attended in school and by the type of text matter presented to him at this stage.

Recognizing the above facts, I readily accepted the invitation of the National Council of Educational Research and Training to act as Chairman of the Panel set up to prepare a new and modern textbook suited for use in Indian Secondary Schools.

The present pamphlet is only the first section of the textbook. It deals with 'Some Basic Facts About Life' spread over nine chapters. The subsequent sections will be brought out in due course and when they are all ready the book will also be produced as a single bound unit.

It may be noted that there are several ways of approaching the subject of biology, each having its own merits and demerits. The editors and members of the Panel are convinced that a wide acquaintance with a number of different kinds of organisms, their activities, their habits and their tissues and organs, is essential and basic to the understanding of the general concepts of evolution, ecology, heredity, and cell physiology. This approach, in their opinion, combines not only the pedagogical advantage of proceeding from the known to the unknown but also prevents students from getting lost in the intricacies of the more advanced aspects of biology.

Although evolution is treated separately in two chapters, an attempt has nevertheless been made to acquaint the student with this all pervasive principle during his study of the world of life. Biological phenomena common to plants and animals have been discussed together as far as possible. Technical terms have been kept down to the minimum except when their use is believed to contribute to easier communication and understanding. Important biological discoveries have been dealt with in a historical perspective to give an idea of how science progresses.

It has been our objective to present the subject in an understandable, stimulating and instructive fashion. We shall appreciate receiving comments, criticisms and suggestions. These will be taken into account in bringing out a revised version of the book.

The original drafts of the chapters in the book were contributed by several persons whose names are given below in alphabetical order: Dr. R.N. Chopra, Reader in Botany, University of Delhi; Mrs. E. Gonzalves, Biology Department, St. Xavier's College, Bombay; Prof. N.B. Inamdar, Head of the Department of Zoology, Institute of Science, Bombay; Prof. B.M. Johri, Department of Botany, University of Delhi; Dr. G.N. Johri, Head of the Department of Zoology, Shia College, Lucknow; Dr. L.N. Johri, Reader in Zoology, University of Delhi; Dr. M.S. Kanungo, Reader in Zoology, Banaras Hindu University; Dr. Manohar Lal, Department of Botany, University of Delhi; Dr. S. C. Maheshwari, Reader in Botany, University of Delhi; Dr. L.P. Mall, Reader in Botany, Vikram University, Ujjain; Prof. R.D. Misra, Head of the Department of Botany, Banaras Hindu University; Prof. M R.N. Prasad, Department of Zoology, University of Delhi; Dr. H.Y. Mohan Ram, Reader in Botany, University of Delhi; Dr. B. Tiagi, Reader in Botany, University of Rajasthan, Jaipur; and Dr. H.S. Vishnoi, Department of Zoology, University of Delhi.

There was naturally a good deal of editing work to be done in order to bring the manuscripts into a form suitable for publication, and to add the illustrations to make the text understandable. In this I was ably assisted by my colleague Dr. Manohar Lal whose help was invaluable in looking after the large volume of work associated with such a project.

I was receiving the ungrudging help of several other persons among whom special mention must be made of Mr. G.S Paliwal, Dr. Sipra Guha and Mr. Man Mohan Johri of the Botany Department, Delhi University, who looked after much of the day to day routine and the reading of the proofs. Prof. Ralph Buchsbaum of the Department of Zoology, University of Pittsburgh, critically read through Section III on animals; Prof. W.N. Stewart of the Department of Botany, University of Illinois, gave many useful comments on Section II dealing with plants; and Dr. S.C. Maheshwari of the Department of Botany, University of Delhi, read Section IV on

physiology. Two school teachers—Mr. S.M. Sharma of the Harcourt Butler Higher Secondary School, and Miss Katherine Bolton of St. Thomas Girls' Higher Secondary School—went through some of the chapters and offered several helpful suggestions. Most of the illustrations were made by Mr. D.M. Sonak. The help received in the form of photographs and other copyright material is acknowledged in the captions.

I must add that the book might never have seen the light of the day but for the constant help and generous cooperation of the following officers of the National Council of Educational Research and Training: Shri Raja Roy Singh, Joint Director; Shri P.N. Natu, Secretary; Dr. R.N. Rai, Head of the Department of Science Education; Mrs. S. Doraiswami, Chief Publication Officer, and Mr. S. Doraiswami, Secretary of the Biology Panel.

Delhi
September 1, 1964

P. MAHESHWARI
Chairman, Biology Panel,
National Council of Educational Research and Training

Preface

IN the midst of the present remarkable achievements in rocketry, nuclear energy, synthetic plastics and fibres, and exploration of space, the study of living organisms, their functions and their importance is frequently minimized or overlooked. It is often forgotten that the primary aim of science, apart from the satisfaction of intellectual curiosity, is the survival and welfare of man. Nothing has contributed more to human welfare and to the very emergence of man from his early animal behaviour, than the knowledge of plants, animals, and his own body. It is said that there are four chief ravages of humanity—diseases, wars, famine, and now over-population. From man's point of view, therefore, biology is the most fundamental and important of all the sciences. It affects vital state policies on matters like conservation of natural and human resources, radiation experiments, population control, quarantine and health programmes. Biology also helps us answer such personal questions as what determines sex, who is responsible for the sex of the baby—the mother or the father; how are twins born, why do babies resemble their parents; how do we acquire immunity against a disease, why do we become enfeebled in old age; how are plants and animals interdependent, and so on. Sanitation, nutrition, pest control, and other attributes of intelligent citizenship—all require a biological background. Finally, biology—a study of the unity as well as the diversity of plant and animal life—is an intellectually enlightening and aesthetically satisfying experience. Indeed, in view of its importance in everyday life, biology should be made a compulsory subject for all school boys and girls. For all this we need adequate textbooks which present the subject in a satisfactory manner keeping in view the needs of the country for which the book is written. The present book is an attempt in that direction.

Should Botany and Zoology be Taught as Separate Subjects? The book adopts, in so far as possible, a common treatment of plants and animals and attempts to emphasize the basic unity in the organization and functioning of living matter. This might appear at first sight to be rather undesirable to those who are used to teaching botany and zoology as separate, well-defined subjects with little or no similarity. They might indeed question

the commonness between a cow and a *neem* tree. To such critics we owe an explanation right in the beginning.

In the 19th century there was a tendency towards compartmentalization of subjects but the insight into the life processes acquired in the past 50 years has shown how these compartments merge into each other. Recent work on cell physiology with the newer techniques of biochemistry and biophysics has particularly called attention to a basic commonness between plants and animals. This common ground also extends into the fields of genetics, cytology, evolution, physiology and electron microscopy. There is no reason why at the higher secondary stage the student should not be appraised of these broadening horizons. So far as some other aspects are concerned, the book still retains separate sections on plants and animals. It may be added that in English and American schools a composite biology course has been in use for the last 10 to 15 years and some universities too have recently begun to offer similar courses at the B.Sc. level.

Even at the research level, many well-known laboratories in the U.K. and the U.S.A. have a common unit for work on both plants and animals. If we are to train the younger generation for successful careers in biological research, it is necessary to orient our school courses in such a way that they get the right perspective of the subject. It may also be pointed out that the school biology course would be the only one which many of our boys and girls will ever attend in their life.

Biology in the Twentieth Century. The 19th century biologists concerned themselves mainly with the morphology and anatomy of plants and animals. While this was natural, the subject has undergone much change in its content and character in the 20th century. This has been made possible largely by the availability of new techniques of chemistry and physics although many milestones have also been laid purely by keen observation and logical analysis. The rediscovery of Mendel's laws of heredity infused new interest into the field of genetics and the mechanism of inheritance was firmly established. Artificial means of inducing mutations in plants and animals were discovered and the genes responsible for the expression of a particular character were pin-pointed. Electron microscopy, ultracentrifugation, spectrophotometry and other techniques have further unravelled the intricate machinery of the living cell and these studies have now gone as far as the isolation and artificial synthesis of the hereditary substance—DNA. The study of enzymes, which was a minor discipline in the last century, has grown into a vast area of research. Our knowledge of vitamins, hormones and antibiotics is also a gift of the present century biology. An understanding of the mechanism of nerve action, brain functioning, photosynthesis, respiration and a host of other physiological processes is also derived from the researches of the last 40 years. To this list may be added the still more recent disciplines like virology, radiation and space biology, the cure for cancer and heart diseases, and finally the attempts to synthesize life itself!

Thus, the emphasis has largely shifted from a descriptive and morphological treatment to the functional aspects. It is apparent that if we continue to train our students only in 19th century biology, as indeed is being done in most of our schools and colleges, they will find themselves unsuited to the future needs of the scientific world.

The Need For Change. One factor which makes the present courses rather dull is that their contents are mostly or entirely descriptive. We think that the morphological part must still form the basis of biology and has to be done well but this cannot be the only part and that physiology, ecology, evolution, the interrelations between plants and animals, and the role of biology in human life are subjects that cannot be left out of consideration. A large fund of biological information acquired during the present century finds no mention in most Indian texts, nor do they provide any information about the interdependence of plants and animals. Indeed, many of the existing books are as much as 50 years behind current biological thought. It is perhaps true that some aspects of biology, involving a rather intensive knowledge of chemistry and physics, are too advanced and complicated to be understood by the school student. However, recent tests on the learning potential of young students have clearly shown that the general principles of physiology and genetics can be effectively taught provided a simple and popular approach is adopted and there is some demonstration material for illustration. For instance, problems like—what happens in photosynthesis or respiration and how living organisms respond to external and internal stimuli—elicit greater interest in the minds of students than learning the characters of a family of plants or describing the pectoral girdle of frog. Similarly, on the practical side, the young student will take much greater interest in experimenting on the digestion of starch by an enzyme than in sketching the shapes of leaves and bones. It would be appalling if a school student should get the impression that biology is nothing more than cutting up frogs and collecting hay, or just a system of naming plants and animals in unfamiliar language.

It is sometimes argued that our textbooks are already encyclopaedic and that it is hardly possible to add more material in view of the time at the disposal of the students. This no doubt poses some difficulty because scientific knowledge is doubling itself every 10 to 15 years. Indeed, the 20th century has provided far more scientific information than the last 5000 years. This knowledge must naturally be incorporated into broad biological concepts so as to become a part of our everyday thinking. To do this one has obviously to cut out certain other portions. Such facts, as are only of an additive nature or matters of unnecessary detail must therefore be pruned and the dead wood removed here and there. To take a specific instance, a student need not spend too much time in learning the variations in the organization of flowers or vertebrae. Since everything cannot be taught at the school stage, a judicial balance has to be struck between depth and breadth.

Another surprising factor is that past courses in India in this subject have virtually excluded the study of human biology. While the students have been studying in detail the various types of roots and stems as well as the smallest bones of a frog, they remained wholly ignorant of their own body.

The Book. The book has been divided into seven, more or less independent, sections. In the first section the student is introduced to the subject matter of science, particularly biology, and the characteristics of the living matter. A glimpse of the variety of plant and animal life prepares the student for a more detailed study of these forms in the second and third sections. The fourth section treats the main physiological processes in animals and plants in a simple way. The fifth is devoted to a comparative account of the different modes of reproduction in the plant and animal kingdoms. Heredity, evolution and ecology form the sixth section of the book. The epilogue to the book covers topics like human diseases, interdependence of plants and animals and the role of biology in human welfare.

We have much pleasure in presenting this book to the students and teachers of the Higher Secondary Classes and shall try to incorporate any suggestions for improvement in the next edition.

Department of Botany,
University of Delhi

Editors : P MAHESHWARI
MANOHAR LAL

The National Council of Educational Research and Training wishes to thank the Chairman and members of the Biology Panel and the Central Board of Secondary Education for their contribution and help in the preparation of this book and its introduction for use in the schools.

The Council invites teachers and all who are interested in education to send their suggestions on the book.

RAJA ROY SINGH
Joint Director
National Council of Educational Research and Training

BIOLOGY

This textbook is prepared by the Biology Panel set up by the National Council of Educational Research and Training. It will be used as a textbook for the elective course in biology in Higher Secondary Schools. The Central Board of Secondary Education has prescribed it for use in their secondary schools under the Board from the year 1964-65.

THE PANEL MEMBERS

1. Prof. P. Maheshwari (*Chairman*)
Head of the Department of Botany
University of Delhi
Delhi-6

2. Dr. N.B. Inamdar
Professor of Zoology
Institute of Science
Bombay

3. Dr. L.N. Johri
Reader in Zoology
University of Delhi
Delhi-6

4. Prof. R.D. Misra
Department of Botany
Banaras Hindu University
Banaras

5. Dr. L.P. Mall
Department of Botany
Victoria College
Gwalior

6. Prof. B. Tiagi
Department of Botany
University of Rajasthan
Jaipur

7. Dr. Manohar Lal
Department of Botany
University of Delhi
Delhi-6

8. Prof. B.M. Johri
Professor of Botany
University of Delhi
Delhi-6

9. Dr. H.S. Vishnoi
Lecturer in Zoology
Department of Zoology
University of Delhi
Delhi-6

10. Shri S. Doraiswami (*Secretary*)
Department of Science
Education, NCERT
H-2/3 Model Town
Delhi

Contents

CHAPTER 1

The Aim and Study of Science

THE twentieth century has sometimes been called the atomic age because of the great strides that have been made in atomic research for peaceful as well as destructive purposes. Space age is yet another expression for this century. Man has gone round the earth in space ships and it is hoped that people from this planet will soon be able to visit the Moon, the Mars, and other planets.

Although the expressions atomic age and space age aptly describe this era, it would be more correct to call it the age of science, for in addition to the achievements described above, many more and equally significant advances have been made in other branches of science.

Our lives today are more comfortable because of science. Our forefathers travelled in bullock carts and took weeks to go short distances, whereas now-a-days we are able to go round the world in a few hours by plane. Dreadful diseases—such as smallpox, pneumonia and tuberculosis—have been brought under control to a great extent. The radio brings us the voices of people from different parts of the world. To these few examples you can add many more. You have only to look around you—in your home, in the streets, in a modern farm, in mills and factories, and in laboratories—to realize that science influences man's life in many ways. Though the results of scientific research may be put to destructive uses, especially by unscrupulous politicians, the primary aim of science has been to give mankind greater security, better health and a happier life. Science has also helped us understand Nature more fully and banish our superstitions and fears. Yet, what exactly is science? Though we know how the word 'science' was coined (science comes from the Latin word *scientia* which means knowledge), a precise definition is not easy.

Many definitions of science have been given. Two of these appear to be more appropriate. First, science may be regarded as a search for the reasons of things. The second definition calls it systematized knowledge based on facts or truths known by actual experience or observation. Jointly these definitions give a fairly correct idea of what is science. The child who pulls a watch to pieces just to know why it ticks is not a scientist, for though he is looking out for the causes of the ticking he is not doing it thoughtfully or methodically. He cannot draw any conclusions from his act. Science consists not in merely trying to know how things happen but in organizing the knowledge thus obtained and making it available to others.

The Origin of Science

Science can be traced back to the time when primitive man tried to explain natural occurrences such as a shower of rain, the thunder of clouds, the growth of a plant, the hatching out of a chick from an egg and so on. The explanations given for these occurrences were often fantastic or superstitious. For instance, rain was regarded as the tears of heavenly beings, and thunder as sounds made by quarelling angels! Although the explanations were often ridiculous, they indicated that man had started on his search for the causes of natural phenomena. Since then he has been continuously discovering new facts, and putting them together to obtain a correct picture of the world and of the men, animals, and plants that live in it. However, a mere collection of facts does not form science unless they are based on what is called the scientific method. There are several steps in this method, but often a problem can be solved without using all the steps.

Steps in the Scientific Method

1. Recognizing and defining the problem to be solved. The scientific method starts with recognizing a problem—something which arouses one's curiosity or something which one likes to find out about A clear mental picture of the problem then takes shape and one is able to state it clearly.

2. Preliminary observation and marshalling the previously known facts. This step includes finding out from books or from reliable persons what is already known about this problem. One may also draw upon one's own past experiences or perform fresh preliminary experiments to gather all suggestive information.

3. Making guesses or hypotheses based on the collected information. Based on facts and past experiences, one thinks of as many possible answers as one can. This step appears to be unscientific because it involves guessing. The guesses are called hypotheses. From these the one that seems to be the most correct is selected. This is sometimes called a 'working hypothesis' because from this one works forward.

4. Experimentation. This is the hardest step in the scientific method. A hypothesis may appear to be correct, but unless it is proved to be so, it cannot be accepted as a scientific fact Experiments are the means by which scientific facts are established. Often the plan of an experiment needs to include a 'control'. A controlled experiment requires two identical experiments in which every condition is the same except one. Suppose, for example, you want to test if a given sample of seeds will germinate earlier in dark than in light In doing this you take two similar pots and sow an equal number of seeds in each from the given sample. Put one pot in a dark chamber and the other in light. The latter is your control pot In the two experiments all the conditions are similar except the one whose effect you wish to study, namely, light.

5. Drawing logical conclusions. In this final step one evaluates the results of his experiments to see whether they justify his hypothesis. If they do not, new hypotheses are thought of and tested. If the experimental results support the hypothesis, one makes a general statement or a principle which is an answer to his original question.

These are then, the steps or elements of scientific method. You can use the same method in solving even your everyday

problems since it is the most systematic and sensible approach

Pure and Applied Science

Some scientists take pleasure in doing research for the sake of a better understanding of Nature. They perform experiments mainly to satisfy their curiosity. They are not concerned with the practical applications of their results. The activities of these scientists are called **pure or fundamental science.**

Other scientists prefer working on problems which are primarily concerned with giving man new and better products or services. This type of work is called **applied science.**

What type of research would you prefer to do? 'The applied research' is perhaps your answer because it seems to offer greater comfort and easier life to humanity. True, most modern amenities are the inventions of applied scientists but the long history of science reveals that the greatest benefits have resulted from researches that were carried out to satisfy curiosity rather than with a hope of gain. You will have a chance to read about such discoveries in some chapters of this book.

The Scientific Attitude

The pursuit of scientific method calls for a special way of thinking and acting towards ideas and events—the scientific attitude. Now that you have also taken up the study of science, you will naturally try to cultivate such an attitude. Even though you may not plan to follow a career in science, this attitude will help you live more intelligently and become a worthy citizen.

A scientist is full of a lively curiosity about the natural things happening around him. He seeks to learn the causes of all phenomena. He firmly believes that every occurrence, however strange, has a cause or basis. Whenever someone calls a thing mysterious, all that a scientist means by it is that we do not yet understand it fully. Any statement, not supported by adequate proof, does not satisfy him. That is why he pays no attention to the tall claims of the healing powers of quacks (Fig 1.1) Whenever afflicted by a disease he goes to a trained medical practitioner (Fig. 1.2)

A scientist's ideas about things are never fixed or unchangeable; he is prepared to revise his opinion if a more complete knowledge of the subject demands it.

A scientist does not believe in superstitions. He is sure that these are the result of wrong judgement and the lack of a proper control experiment. A person with a scientific outlook boldly rejects such superstitious beliefs as: people with skin of one colour are superior to those with skin of another colour; breaking a mirror will bring bad luck; or living in a room numbered 13 will result in illness or poverty.

In solving his problems the scientist does not follow a careless and hasty approach. He prepares and carries through a careful and complete scheme of work. He makes his observations carefully, accurately and honestly. He is determined to weigh all the evidence before arriving at any conclusion and makes sure that his evidence is sound, sensible and complete enough to justify his conclusions.

A scientist's personal likes and dislikes do not influence his judgement. He is never in a hurry to draw conclusions; he has the patience to wait and collect more evidence to find a true answer.

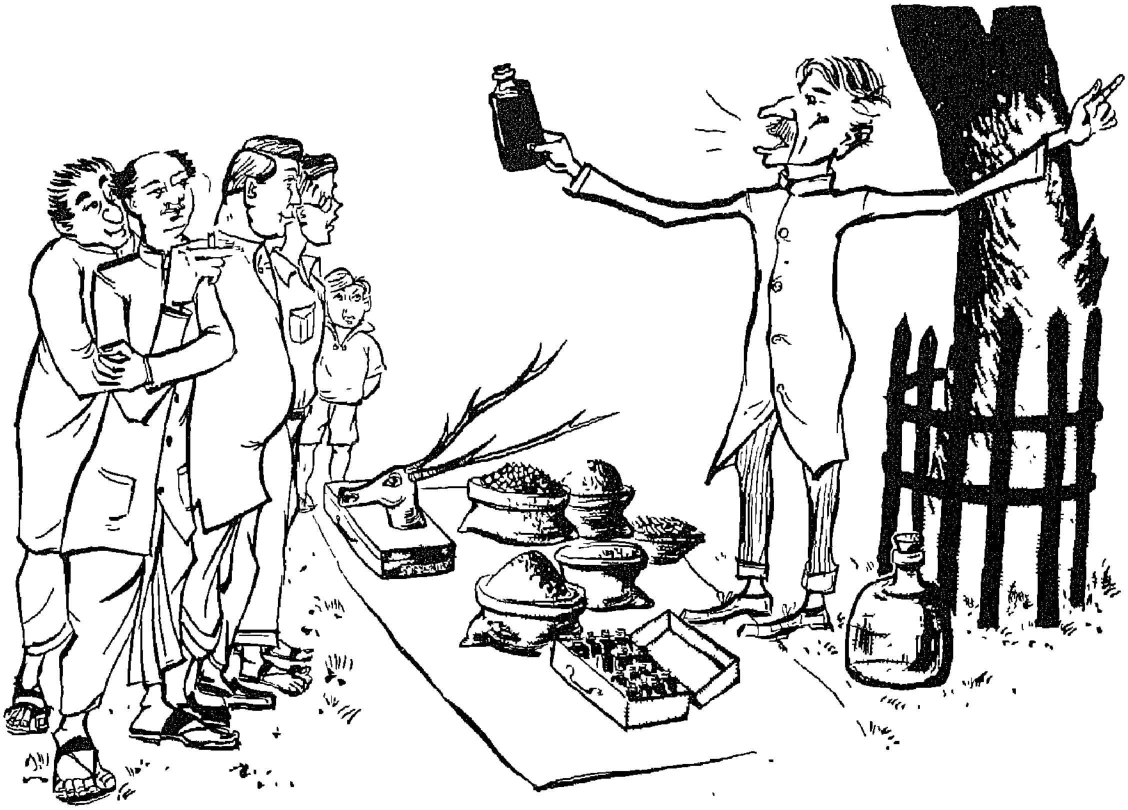

Fig. 1.1. The quack doctor makes tall claims of the curing powers of his drugs. Why does a man with a scientific attitude have no faith in these?

Lastly, a scientist always respects other people's ideas, opinions and ways of life even if they are different from his own. The scientist is never prejudiced. He maintains an open mind and realizes that mastery over a subject is not confined to any group, race or religion. While he prefers to collect his own facts by experimentation and observation, he is, at the same time, willing to use the conclusions drawn by other competent workers. He sees no point in duplicating the effort of earlier workers if their concepts are based on correct methods and sound reasoning.

Fig. 1.2. **A modern doctor. Why does she command more respect ?**
Courtesy of the United States Information Service, New Delhi.

SUMMARY

Ours is the age of science. Science is a rapidly advancing area of systematized knowledge. Its impact on humanity is felt in every walk of life.

The large body of scientific information is based on work done according to the scientific method This involves several steps: defining the problem, making preliminary observations, suggesting a suitable hypothesis, experimentation, and drawing logical conclusions. The conclusions serve as foundations for new scientific studies. The scientific method can also be profitably used in our daily life. It teaches us to draw conclusions after careful study, and not before collecting and analyzing the facts.

The true scientist has a scientific attitude towards his work. Curiosity, disbelief in superstitions, open-mindedness, patience and courage are the chief elements of this attitude.

Scientific experiments done merely for providing an explanation of a natural phenomenon are as valuable as those done for immediate gain.

QUESTIONS

1. What is a control experiment? Devise control experiments to test the following:
   a. If a cat crosses one's way, one is bound to have bad luck.
   b. Butterflies are attracted towards flowers because of their colour (red and orange) and not because of their sweet smell.
   c. Plants use up a part of the soil in which they grow.
2. How can the methods of a scientist help us in daily life?
3. The work of some scientists does not seem to solve any practical problem, yet they are encouraged to continue such work. How is this justified?
4. Give the five steps a scientist takes in obtaining reliable information.
5. Make a list of some common superstitions in your society. What, in your opinion, might have led people to believe in them in the first instance? Why are they still persisting?
6. What are the main elements of the scientific attitude?
7. Name some outstanding scientists of today.

FURTHER READING

BRONOWSKI, J. 1951. *The Common Sense of Science.* Heinemann, London

CLOUDSLEY-THOMPSON, J L. 1960. Science and Pseudo-science. *School Science Review* Vol.41 pp.386-391.

CONANT, J.B. 1947 *On Understanding Science.* Yale University Press, New Haven.

CONANT, J.B 1951 *Science and Common Sense.* Yale University Press, New Haven.

DAMPIER, W C. 1942. *A History of Science.* The Macmillan Company, New York.

POLANYI, M. 1946. *Science, Faith and Society.* Oxford University Press, London.

SINGER, C. 1958. *From Magic to Science.* Dover Publications, New York.

TERMAN, L.M. 1955. Are Scientists Different? *Scientific American* Vol.192 No 1 pp.25-29.

CHAPTER 2

The Science of Biology

BIOLOGY is the study of all living creatures—of yourself, animals, plants, germs and so on. It helps you answer such questions as: what makes a baby male or female, how are twin babies born, and why are they identical or non-identical? What causes disease and what can be done to check it? How is energy stored in food? Why do we become weaker in old age? What types of animals and plants, other than those you are already familiar with, are to be found in the world? How are our lives affected by the other forms of life such as plants, insects and larger animals? The answers to these and many other questions about life form the subject matter of **biology.** Biology is thus closely related to your daily living in many ways. It makes you live more intelligently, more happily.

Biology is intimately associated with many other sciences, i.e. it often uses the methods and findings of other sciences to reveal the mysteries of living things (Fig. 2.1). For instance, if we want to know how a plant manufactures its food or how blood clots on a wound, we need to use our knowledge of chemistry. Similarly the functioning of the eye, especially the principles of image formation, or the conduction of water from roots to the highest leaves of a plant, can be understood only by applying some principles of physics. In fact, new borderline branches of science, such as biochemistry and biophysics, have now arisen which deal with the application of the principles of chemistry and physics to biological problems.

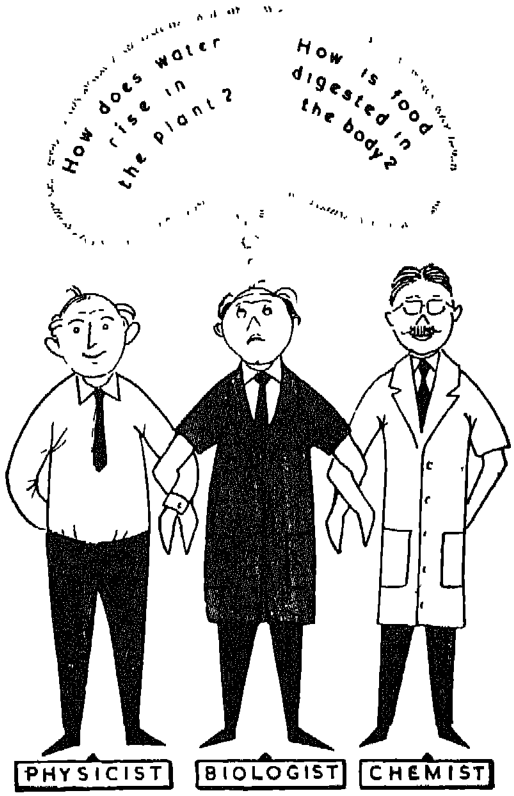

Fig. 2.1. The modern biologist uses the methods of physicists and chemists to understand the problems of life.

The History of Biology

Though the word biology was coined (Gk. *bios*=life; *logos*=study of) only in the year 1802, the study of plants and animals really began as soon as primitive man began roaming about on the earth. As he depended on plants and animals for his existence, he naturally had to study them in order to discover which types he could utilize for food, shelter and clothing, which plants he could use to cure diseases, and which animals he could use for work. The health and disease of his own body, and the birth, growth and death of his children occupied his attention as much as they engage our attention today.

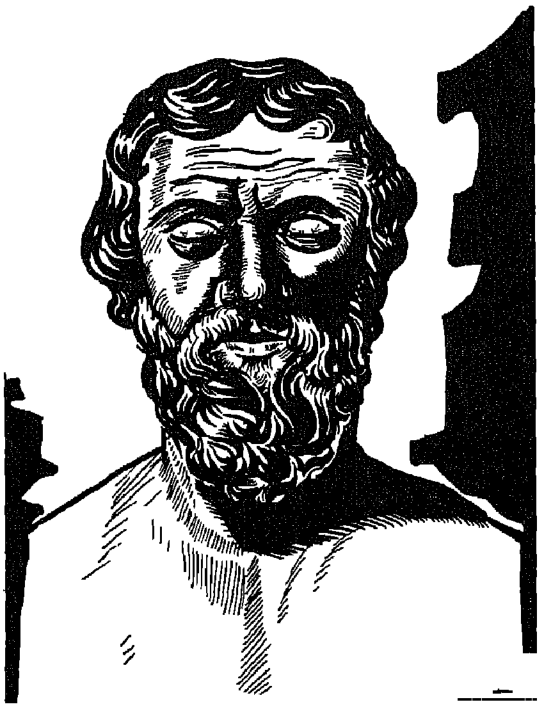

Fig. 2.2. Aristotle (384-322 B.C.), a Greek philosopher who stressed the importance of accurate and direct observations in securing facts and data.

Fig. 2.3. Theophrastus (370-285 B.C.), a student of Aristotle. He is called the 'Father of Botany'. He described 500 plants and wrote 'A History of Plants'. Courtesy of the Department of Botany, University of Delhi.

Although primitive man accumulated a fair amount of knowledge about living creatures, this knowledge was often unscientific. The scientific study of plants and animals began much later in several ancient cultures such as those of Babylonia, Egypt, Greece, China and India. Aristotle (384-322 B.C.) has been called the greatest biologist among the Greeks. Besides many other investigations, he watched and described the development of the chick within the egg with great accuracy. His pupil Theophrastus (370-285 B.C.) gave us accurate descriptions of plants and detailed information about the germination of seeds. Some of the writings of these pioneers are admired even today.

Several ancient Indian scriptures like 'Ayurveda', 'Charak Samhita' and 'Susruta'

Fig. 2.4. Vesalius (1514-1564) the Belgian anatomist stealing the skeleton. From E E Bayles and R W Burnett, *Biology for Better Living*, Silver Burdett Co , New York, 1946

show that our ancestors were fairly advanced in their knowledge of the structure and function of the bodies of plants, animals and human beings. The study of the 'Vedas' (2500 B.C.?), 'Ramayana' (1900 B C.?), 'Mahabharata' (1400 B.C ?), 'Upanishads' (350 B.C.?), and 'Arthashastra' (300 B.C.?) also reveals that our ancestors had a large fund of biological information.

After this period of scientific activity progress was markedly slowed down till almost the end of the fifteenth century. At the beginning of the sixteenth century, research in biology was stimulated by four important contributions. The first significant contribution was made by the Belgian doctor Andreas Vesalius. He published a large treatise entitled *On The Structure of the Human Body* (1543) based on dissections and direct observations, rather than on previous assumptions of the so-called authorities. He stressed that in order to obtain reliable information it was very important to make actual observations instead of blindly following the imaginings of others So great was his zeal for personal observation and experience that he once stole the skeleton of a convict who had been hanged and whose flesh had been eaten away by vultures (Fig. 2.4). The second

Fig. 2 5. William Harvey (1578-1657), the English physician who proved that blood circulates through the body in arteries and veins. Courtesy of the British Information Services, New Delhi

step forward was the discovery, in 1628 by the English physician, William Harvey that blood circulates in the human body and that the heart acts as a pump. This led to rapid advances in the field of medicine. The third contribution, made by Robert Hooke in 1665, was that a thin slice of a plant, when examined under a microscope, appears to be made up of small cavities like those in a honeycomb. Hooke called these tiny cavities the cells. The fourth important discovery, made in Holland in 1676 by Antony van Leeuwenhoek, was that there exists a world of microscopic plants and animals that had never been seen before. Further advances followed at a rapid rate, and in the last 200 years a large amount of knowledge has accumulated due to the labours of biologists all over the world. In this vast field there have been many outstanding discoveries or milestones. You will become acquainted with most of these in this book.

How is Biology Studied ?

The tools and techniques of a biologist are many. Some biologists study plants and animals in Nature. Their requirements may be as simple as a metre rod, a collecting can, a hand-lens and a note-book. Other biologists investigate such life processes as respiration, nutrition, reproduction and the like. They often use compli-

Fig. 2.6. Antony van Leeuwenhoek (1632-1723), a Dutch microscopist, was the first to see bacteria (1676). Courtesy of the Department of Botany, University of Delhi.

cated pieces of apparatus such as those found in the laboratories of chemists, physicists and technologists. However, the most important requirements are curiosity and keenness of observation. Living things are found everywhere—in the streets, in jungles, on mountain tops, in springs, in the air, and even inside your own body! The biologist makes observations on all living things that interest him. He tries to find out how a particular animal or plant behaves as it does. He is struck by and tries to find the reasons for the similarities and differences between various types of organisms. After making preliminary

Fig. 2 7. A student working with a compound microscope. This instrument is a close companion of most biologists. Courtesy of H. Singh, Department of Botany, University of Delhi.

observations he proceeds to verify them by more detailed observations or experiments. For this purpose he often uses a compound microscope (Fig. 2.7). In fact this instrument is such a close companion of most biologists that if you see a set of microscopes in a laboratory, you can be almost sure that a biologist is at work around there.

Biology in Human Affairs

This aspect of biology is dealt with in detail in the last chapter but you will perhaps like to have some idea of at least a few of the numerous fields in which knowledge of biology is helpful.

Apart from the close relationship between biology and some other subjects as agriculture, medicine and fisheries, a knowledge of biology is also necessary in other fields. The methods applied for the preservation of our forests and useful animals are all based on detailed biological studies. In matters such as public health, control of pests, and nutrition, biology plays an important part The departments of public health in our cities are responsible for guarding citizens against epidemics of infectious diseases. These departments can function only on the basis of the knowledge available to them about organisms which cause disease and the way in which such diseases can be checked.

Biology also influences society as a whole. Man has been able to obtain better plants and animals by proper selection An application of the knowledge of heredity could even lead to the improvement of human race. Moreover, men can very well learn to live together amicably by imitating the social life of some of the lower animals such as ants and bees. Even the least of God's creatures may thus have a lesson for man !

Divisions of Biology

We have seen that biology is the study of living objects such as plants and animals. The two main divisions of biology are **botany** (Gk. *botane*= a herb) which deals with plants, and **zoology** (Gk. *zoon*=animal; *logos*=a discourse or a study of) which deals with animals. In addition to these two divisions, another branch of biology which has come into prominence in recent years is **microbiology.** This is the study of such plants and animals which are so small that they can be seen only with the help of the microscope Microbiology deals chiefly with the organisms which cause diseases or are otherwise important. The distinction between these three subjects, as you can see, is based on the nature of the organisms with which they deal. These broad divisions of the subject should not give you the impression that they are separate, unrelated compartments with little or no similarity to one another These divisions are helpful when we study the external form of different organisms like plants, animals, and microbes In their life processes all living beings are similar to one another. As an example of this commonness it may be stated that the mechanism of respiration and the laws governing heredity are just the same in all living organisms.

Plants and animals may be studied in different ways. Each of these ways forms a distinct branch of biology and is given a special name (Fig. 2.8).

Morphology is the study of the external and internal form of the organisms. It is subdivided into (a) **anatomy** or the study of the gross internal structure of the organism or of its separate parts; and (b) **histology** or the study of the microscopic structure of tissues.

Cytology is the study of cells—the small units of which plants and animals are composed.

Embryology is the study of the early development of plants and animals. It deals with the formation and development of embryo.

Physiology deals with the functions of the various parts of the organism. Plant physiology deals with nutrition, growth, reproduction, and movements of plants. Similarly, animal physiology deals with the corresponding functions in animals.

Palaeontology is the study of the remains of the plants and animals which lived millions of years ago and which are now preserved in rocks as fossils. The study of this branch of biology helps us to understand how plants and animals evolved.

Taxonomy is the study of the classification of plants and animals. The number of known plants and animals in the world is very large. Every day the number is increasing, as more types of each group are being discovered. These plants and

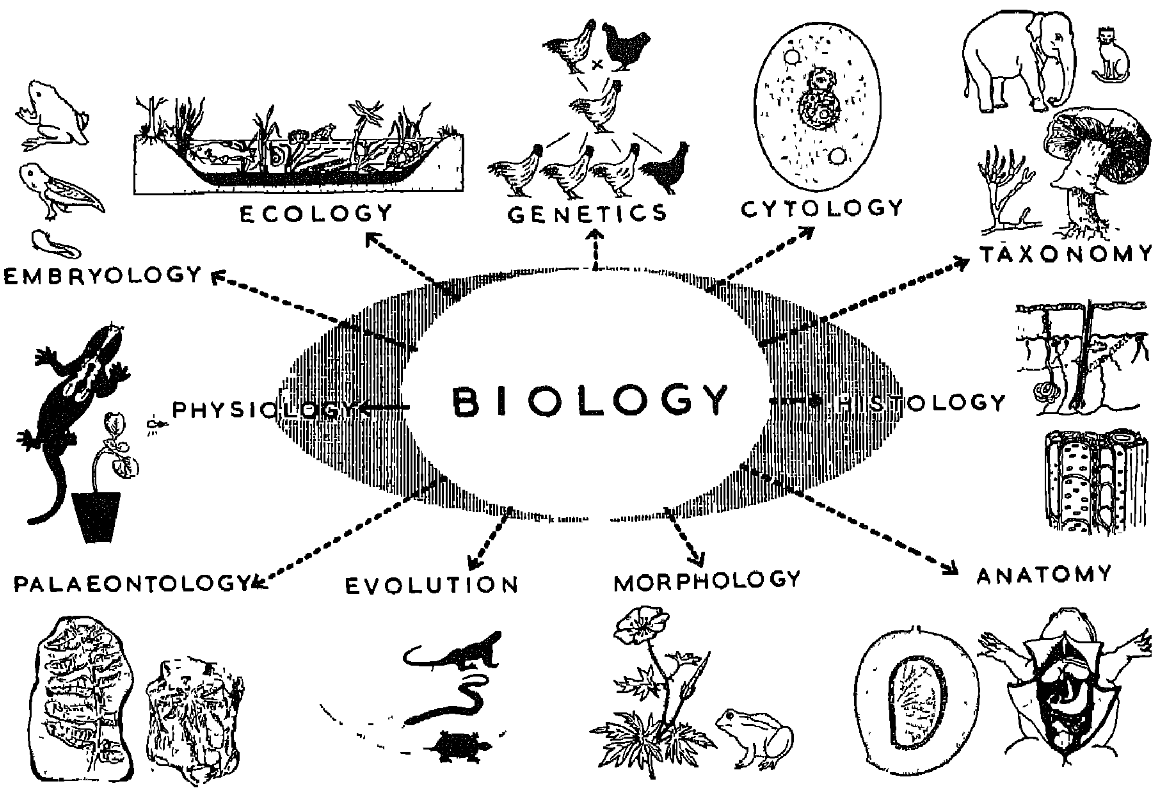

Fig. 2.8. The various disciplines of biology. Courtesy of the Department of Botany, University of Delhi.

animals of various kinds must, for convenience, be classified into different groups to indicate their resemblances and relationships. They must also be correctly identified and named. The taxonomist takes the help of morphology, palaeontology, cytology, biochemistry and other branches of biology to evolve a correct classification of plants and animals.

Ecology is the study of organisms in relation to the world around them, that is, to their living and non-living surroundings. The non-living factors include temperature, light, water, soil and so on, while the living factors are the other organisms, including man.

Genetics is the study of the inheritance of characters. It tries to explain the similarities and differences between parents and offspring in terms of the factors responsible for this behaviour.

Organic evolution is one of the most important themes of biology. It tells us how simple forms of life changed into more complex forms, leading finally to the appearance of the highest evolved types—man and flowering plants.

Careers in Biology

We have said that it is essential to study biology in order to live a better and healthier life. You might also like to know whether one can take biology as a career in life. Yes, certainly! Biology provides ample opportunities of employment You may become a research scientist and devote your time in investigating the fundamental processes of life, or you may become a teacher in biology in a school, college or university. With a sound knowledge of growing different types of plants you can become a farm scientist and help the farmer in growing better crops. You can also become a horticulturist and breed new and fanciful varieties of ornamental plants. In case you are interested in microbes, or in diseases of man himself, you could take up the career of an industrial microbiologist, bacteriologist, a medical doctor or a nurse. May be you find the study of forests more fascinating than all others and would like to conserve and improve the forests. You could also be employed as a health officer to help in problems of public health and hygiene. Some modern industries like those engaged in the production of alcohol, cheese, vaccines and antibiotics (such as penicillin) also need the help of persons trained in biology

SUMMARY

Biology is the study of various aspects of living objects—plants, animals, and germs. It helps us toward a better appreciation of Nature and to live a healthier life.

Although many ancient nations had some biological knowledge, the systematic study of life began only in the 16th century. The main attributes of a good biologist are a power

of keen observation, and a sufficient knowledge of the related sciences, namely chemistry, physics and mathematics. The study of biology offers a wide range of careers in both fundamental and applied fields.

The three main divisions of the subject are: (a) botany, which deals with the study of plants, (b) zoology dealing with animals, and (c) microbiology concerned with microscopic organisms which cause diseases or are otherwise important The various aspects of this study come under several disciplines such as morphology, physiology, ecology, genetics, palaeontology and evolution.

QUESTIONS

1. Which phase of biology is involved in the following studies?
   a Inheritance of curly hair.
   b. The emergence of man from ape-like ancestors.
   c. The effect of alcohol on body.
   d. The types of plants and animals inhabiting caves, mountains, ponds, deserts, etc.
   e Microscopic structure of human brain.
2. Why should a student of biology have a good knowledge of physics and chemistry?
3. Supposing someone argues · 'My grannie knows nothing of biology, yet she has been leading a perfectly healthy life' Discuss how you will convince the questioner about the importance of the study of biology.
4. Name at least five great discoveries in biology made in the present century.
5. What are the requirements of a good biologist ?

FURTHER READING

BAYLES, E.E. and BURNETT, R.W. 1946. *Biology for Better Living* Silver Burdett Co., New York.

BIBBY, C. 1946. *How Life is Handed On.* Thomas Nelson and Sons Ltd., New York.

GABRIEL, M.L. and FOGEL, S. 1955. *Great Experiments in Biology.* Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

GAMOW, G. 1953. *Mr Tompkins Learns the Facts of Life.* University Press, Cambridge.

TAYLOR, G.R. 1963. *The Science of Life: A Picture History of Biology.* Thames and Hudson, London.

CHAPTER 3

Life and Its Characteristics

IF you were asked whether you could distinguish the living from the non-living, you would immediately answer in the affirmative. You would point to a tree, a fly, a bird, or perhaps, to your baby brother, as examples of living objects, and to a stone, an electric bulb, a piece of iron, or a chair, as examples of non-living ones. Further, you would say that it is extremely easy to tell a living object from a non-living one, for a living object breathes, moves and grows, while a non-living one does not do so. You could also say that objects at one time blessed with life but now lifeless are called dead Examples of these are wood and cork, which originally formed part of a living tree, and bath sponges, which were also alive at one time. We thus have good examples of three kinds of things. living, non-living, and dead (Fig. 3.1). Yet, can we say what life is? To define life is not easy. A simple but not very satisfactory definition would be: 'Life is the power that plants and animals possess to maintain and to produce other forms like themselves'. But as you will realize a little later, even this definition is not quite satisfactory. Actually life is not a thing or a substance. It is a process or a series of processes which are intimately related to each other The sum total of all these processes constitutes life. In the study of living things we do not observe life itself, but we study the chief characteristics of living organisms. Let us now consider the various attributes of life.

Cellular Structure

All living creatures are made up of one or more well-defined tiny masses of living material or **protoplasm** (Gk *prōtos*=first; *plasma*=form or mould) enclosed by a membrane. Each of these tiny structures is called a cell Thus, if you examine a thin slice of any plant or animal body under a microscope, it will be seen to be composed of a number of cells or compartments each filled with the jelly-like protoplasm. Non-living objects such as a honeycomb may have cells, but they lack this fluid and are therefore not living. Protoplasm is the primary living substance. Chemically, it is composed of water, sugars, amino acids, proteins, fats, nucleic acids and certain mineral substances or salts. By itself none of these substances is living but together they may produce the living substance called protoplasm. However, scientists have not so far succeeded in making protoplasm by artificially combining these simple substances.

LIVING, NON-LIVING, AND DEAD OBJECTS

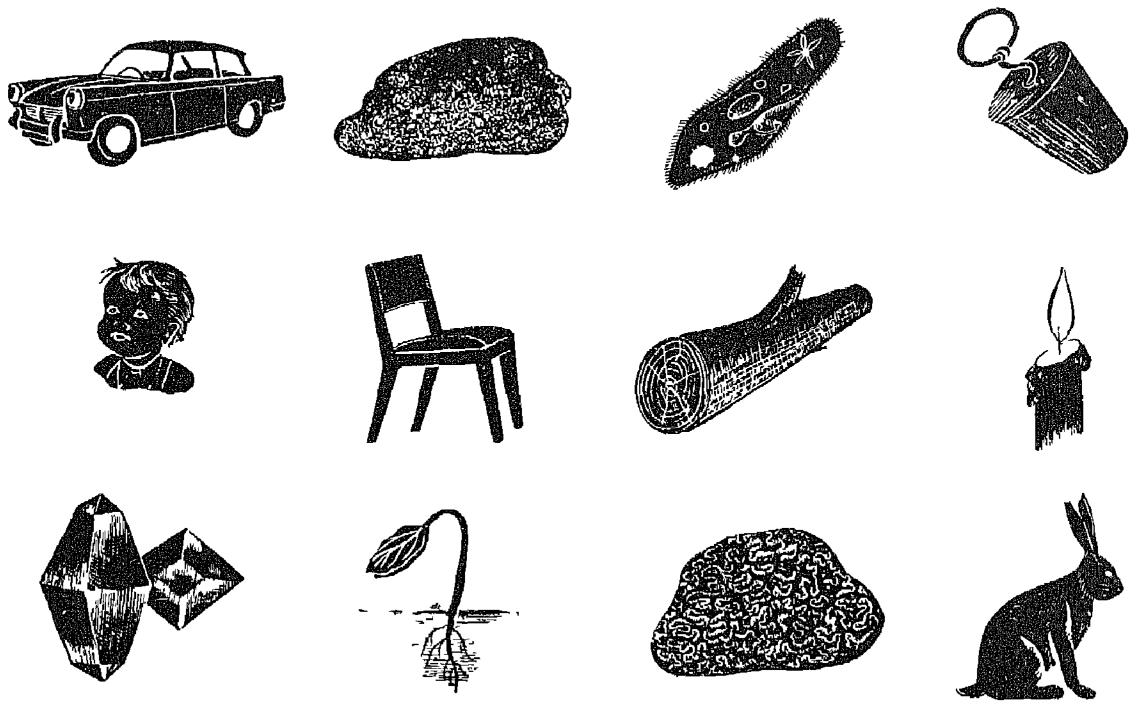

Fig. 3.1 Living, non-living and dead objects. Which of these objects are living? Which are non-living? Which of them were once alive but are now dead? Give reasons for your answer in each case. First row left to right—motor car, bath sponge, *Paramecium*, bottle cork. Second row left to right—child, chair, log of wood, candle. Third row left to right—crystals, seedling, corals, rabbit.

Growth

It must be a matter of common experience to you that all living organisms grow. The helpless baby soon grows into a crawling infant, equally soon, he is able to toddle. A little later, he can hold himself upright and walk. The *Eucalyptus* trees of Australia attain a height of over 100 metres, the giant bamboo grows over 30 cm a day during its active period of growth. This universal phenomenon of growth, although varied in speed and magnitude, is an essential character of all living organisms.

Growth may be defined as the ability of living organisms to take chemical substances from their surroundings, to combine these substances in various ways, and finally, to convert them into the material of their own bodies. This leads to an increase in size accompanied by a permanent change of form.

Many non-living objects also show 'growth'. For example, when a crystal of copper sulphate is placed in a saturated solution of the same salt, it grows in size However, growth in living organisms is different from that seen in a non-living body, such as a crystal In this case the new material is added in the same way as a ball of mud is made larger if more mud is applied to it. On the other hand, growth in living bodies results from the addition of new living substance which in turn is derived from totally different, and mostly non-living, substances. Thus when a small child, fed mostly on milk, fruits and cereals, grows into an adult, he converts these substances into flesh and bones.

Metabolism

The living body is able to carry out the different processes on which life depends. This group of processes is known as **metabolism** (Gk. *metabolē*=change) When a metabolic process is constructive—as when food is produced by a plant, energy is stored, and new life substances are added to the body of the organism—it is known as **anabolism** (Gk. *ana*=up; *bolē*=throw). If the process is a destructive one—as when reserve foods are broken down and the energy stored in them is liberated—it is known as **katabolism** (Gk. *kata*=down, *bolē*=throw). Both anabolic and katabolic processes may go on simultaneously in the living body. If the constructive processes are in excess of the destructive, the organism increases in bulk, i.e., it grows. When the two processes are equally balanced, the organism just maintains itself. After the period of adult life, the destructive processes gradually exceed the constructive ones and a period of slow decay, called old age, begins. This continues till a stage is reached when some vital portion of the organism gives way, and it ceases to live. In other words, it dies

The following important metabolic processes take place in a living body:

Nutrition. Every living organism needs to take food in order to remain alive (Fig. 3.2) The preparation and utilization of food is known as **nutrition.** A green plant prepares its own food from simple substances, such as water, mineral salts

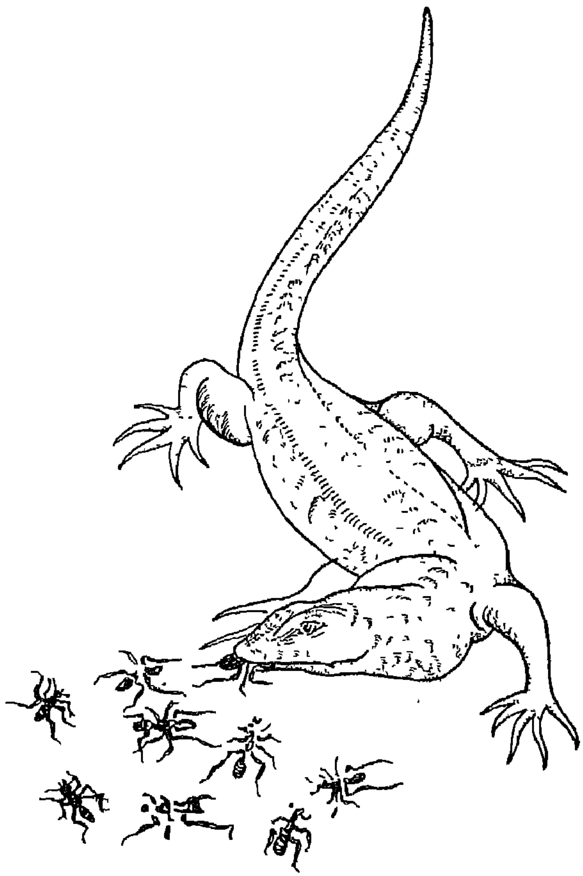

Fig. 3 2. A lizard catching its prey. All living things require food.

(obtained chiefly from the soil) and carbon dioxide (obtained from the air). In the presence of light it converts them into sugar from which complex chemical compounds, such as proteins and fats are produced. Animals take in ready-made food prepared by green plants or they eat the flesh of other animals which in turn feed on plants. The taking in of food is known as **ingestion.** The food is again broken down into simpler substances in the animal body. From these substances the body prepares more complex compounds needed to build its tissues. In other words, the newly formed substances are **assimilated** in the body.

Respiration. The living body has to perform a number of functions: it has to move, it has to replace the worn-out parts, it has to grow and it has to do many other tasks of life. All this work requires energy which is obtained by the process of **respiration.** Respiration is a visible sign of all life. In this, the oxygen taken in from the air combines with the stored foods and by a series of changes they are broken down into carbon dioxide and water. As a result of this 'burning,' a large amount of energy is liberated much as it happens when we burn coal. Man and most other animals, that you commonly see around, have definite respiratory organs by which they breathe. However, plants and some very simple animals have no definite organs of respiration. In these, the cells of the body directly take in oxygen from the air and carry on respiration. The waste products—carbon dioxide, water and other substances—are got rid of by the organism either by exhalation or in other ways. The common belief that respiration means taking in of oxygen and giving out of carbon dioxide is not quite correct. These are only the accompaniments of respiration; its most important feature is that it liberates energy.

Excretion. Excretion is a process by which waste substances are passed out of the organism's body. The wastes are produced during movements, nutrition, respiration and other life activities. If they are allowed to accumulate in the body, they exercise their poisonous effects and may bring about the death of the organism. Animals throw out such products mostly in the form of sweat, urine and faeces. Plants get rid of waste products, such as gums, resins, and even water, with the help of special cells or from the entire surface.

Movements

All living objects show some kind of movement. It is clearly and easily seen in animals since they have definite organs of locomotion. Although it is not always very apparent, movement is nevertheless quite common in plants. Thus, when a flower opens, its parts spread out by a slow movement. The leaves of the sensitive plant, touch-me-not (*Mimosa pudica*), fold up when touched by hand and open again after some time (Fig. 3.3). The bending of plants towards light is another example of movement. Some lower organisms and the sperms of most plants and animals are provided with small flagella or cilia which show lashing movements and carry the cell from place to place. Moreover, the cytoplasm in many living cells performs a slow, streaming movement.

Certain non-living objects may also show movements. A rock may move if you give it a push. The force which causes the movement of the rock comes from outside. It is YOU who has provided the force. Mechanical vehicles such as the motor car, the aeroplane, the rocket and the satellite also move; but the forces

causing these movements are very different from those which cause the movements of living objects.

Irritability

A property of all living things is that they are irritable. This does not mean that they are bad tempered. It means that they are sensitive to their surroundings and react to them. They have the ability to do things by responding to sounds, heat, smells and other influences. For example, if somebody pricks you with a pin, you jump. If you place a plant near the window, after a few days it bends towards light (Fig. 3.4). Place a saucer of milk on the ground and your cat will run to it. Yourself, the plant and your cat are all alive and have responded or reacted to certain influences or stimuli—you responded to a pinprick, the plant to the light, and your cat to the sight of food. Many non-living things react too. If you press the knob of an electric bell, it rings. It has responded to the stimulus of your touch. Yet nobody will ever think of saying that a bell was alive! Why?

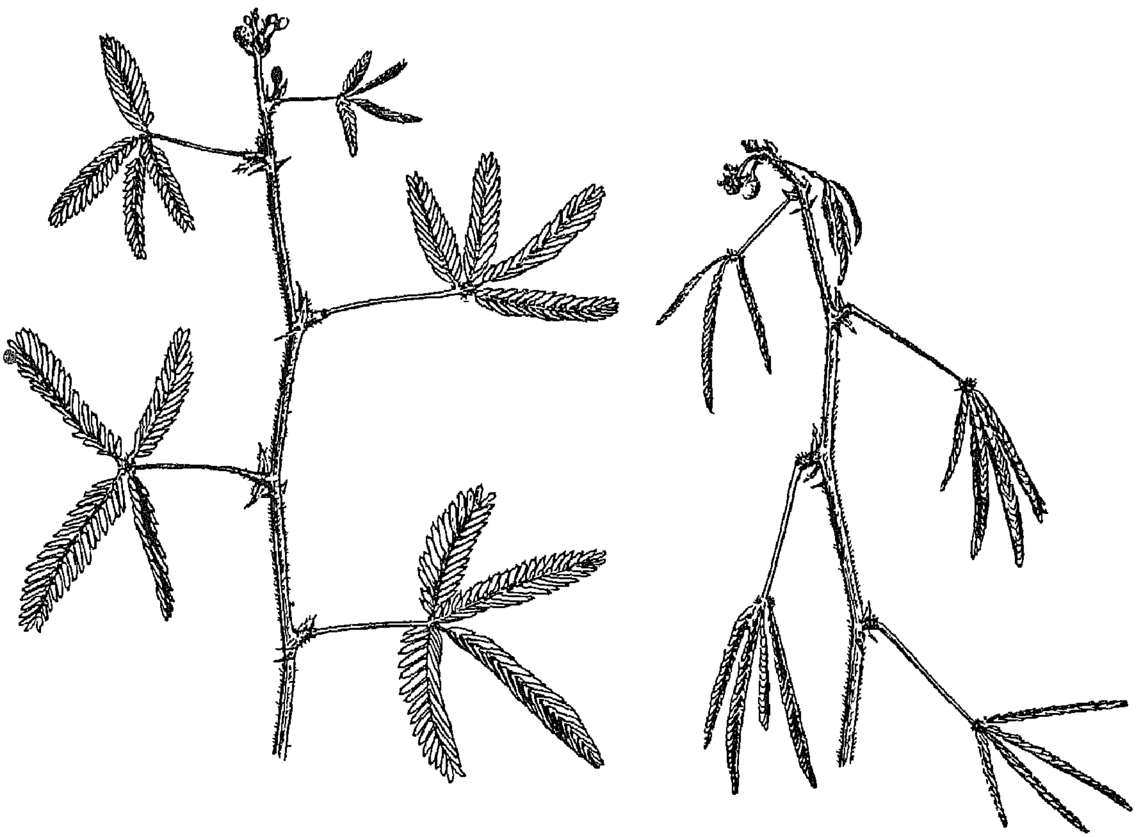

Fig. 3.3. Movement of leaves in the sensitive plant. Left, leaves in normal position; right, position of leaves immediately after they have been touched. Courtesy of the Department of Botany, University of Delhi.

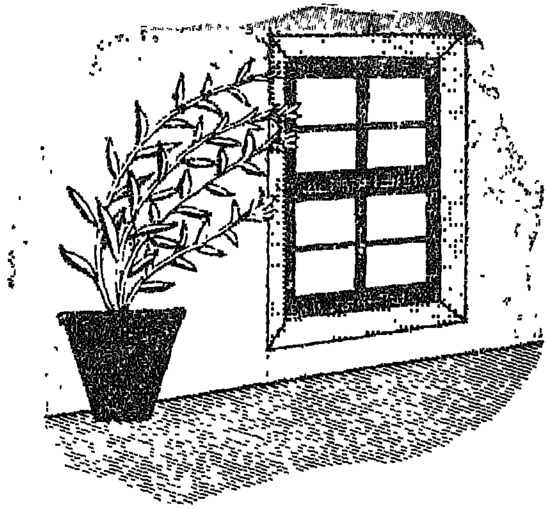

Fig. 3.4. A plant kept in a room near a window bends towards light. All living organisms have the ability to respond to external stimuli. Courtesy of the Department of Botany, University of Delhi

Reproduction

Perhaps the most characteristic feature of all living beings is that they can reproduce—they can give birth to babies like themselves. Non-living things cannot do that. A neem tree produces young neem trees, a bitch produces puppies (Fig. 3 5), and humans produce young humans You never hear a chair producing little chairs or a large motor car producing baby cars.

Young ones or the offspring may be produced in several ways. The protoplasm of a one-celled organism may divide into two or more parts, each of which grows into a new individual (Fig 3.6). That is the way bacteria and many other plants and animals reproduce. They have only one parent which itself disappears but leaves, instead, two individuals In other words the parent changes into its two offspring.

Some plants and animals have another method of asexual reproduction. In these instances the parent does not disappear in giving birth to its young ones. Only a part of the parent breaks off and grows into a new individual. For example, take the familiar potato plant. A single potato, or even a part of it, can give rise to a new plant (Fig 3.7).

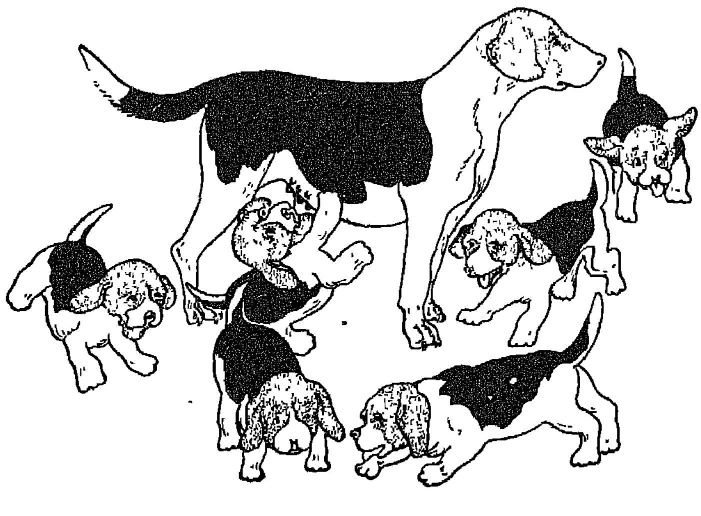

Fig. 3.5. A bitch and its puppies. Reproduction is one of the important characteristics of all living organisms.

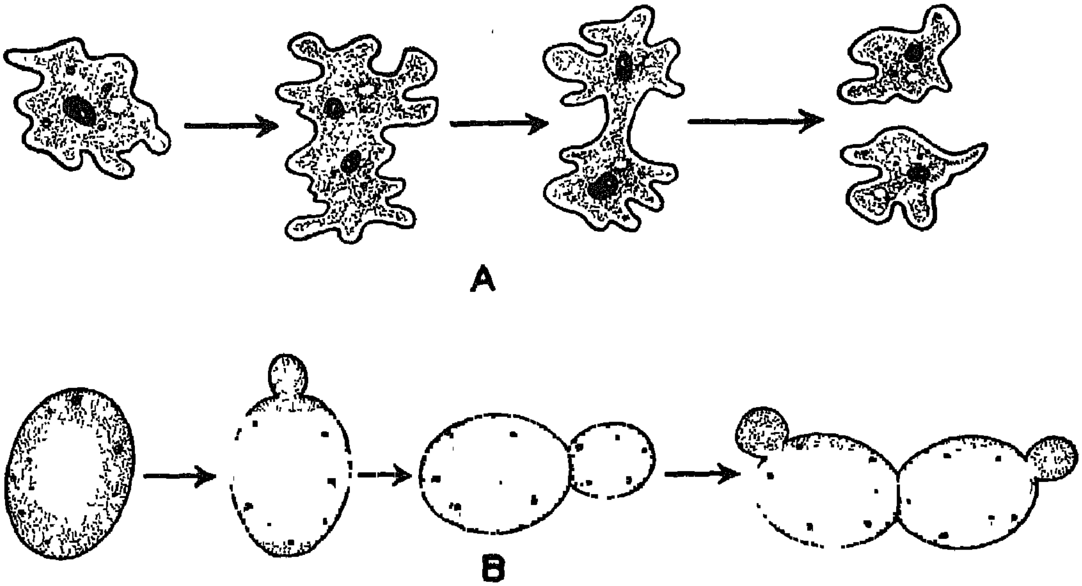

Fig. 3 6. Asexual reproduction in one-celled organisms; the protoplasm divides into two parts each of which grows into a new individual. A. Reproduction in ***Amoeba*****, a one-celled animal. B. Reproduction in yeast, a one-celled plant used in making bread.** Courtesy of the Department of Botany, University of Delhi.

Most plants and animals, that you commonly see around you, reproduce by the sexual method. This involves two parents—a mother and a father. The mother produces **eggs**, the father produces **sperms.** The sperm fuses with the egg. This act is called **fertilization.** The fertilized egg, a single cell to start with, divides and redivides to produce a large number of cells of which the adult plant or animal is made. A remarkable feature of the process of reproduction is that every organism produces offspring only of its own kind. For example, a mango tree will always produce a mango plant and a pair of monkeys will always produce more monkeys. This process of continuity of form from one generation to another is called **heredity.** Biologists have found that it is the nucleus of the cell which contains the ultimate units

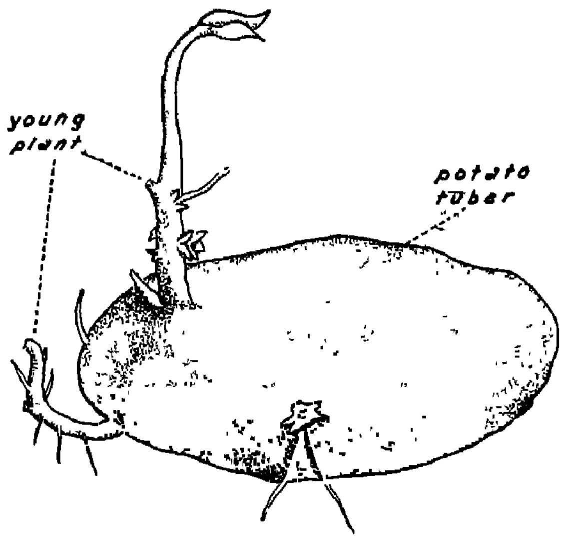

Fig. 3.7. A potato tuber producing new plants. Courtesy of the Department of Botany, University of Delhi.

of heredity. In other words, it carries the characteristics of the parents to the children.

Thus cellular structure, nutrition, respiration, excretion, growth, movement, irritability and reproduction are the basic attributes of life. Things that lack life do not perform all these functions though some lifeless objects can perform one or more of these. For instance, a motor car takes in fuel (food), it distributes the fuel to the carburettor, it sucks in (breathes) oxygen which reacts with the fuel to produce energy, and it eliminates the wastes (smoke). However, the similarity stops here. The motor car cannot grow bigger than what it was when it came from the factory (when it was born!). It cannot produce baby cars and it cannot repair itself. Hence it is non-living.

Biologist's Puzzle—The Viruses

There are tiny things called **viruses** that cause diseases like cold and poliomyelitis. They are much smaller than the smallest bacteria Biologists have argued for years about whether they are alive or not. Most of our criteria of life do not apply to them. They have no cellular organization They can be crystallized (Fig. 3.8) and stored for many years like the crystals of salt or sugar. Outside the living cells, they neither grow nor reproduce, they do not respond to stimuli, and neither breathe nor respire. However, when they enter the cells, they start reproducing or multiplying. They thus have at least one of the essentials of life—the capacity to reproduce. They seem to fall in the twilight zone of living and non-living.

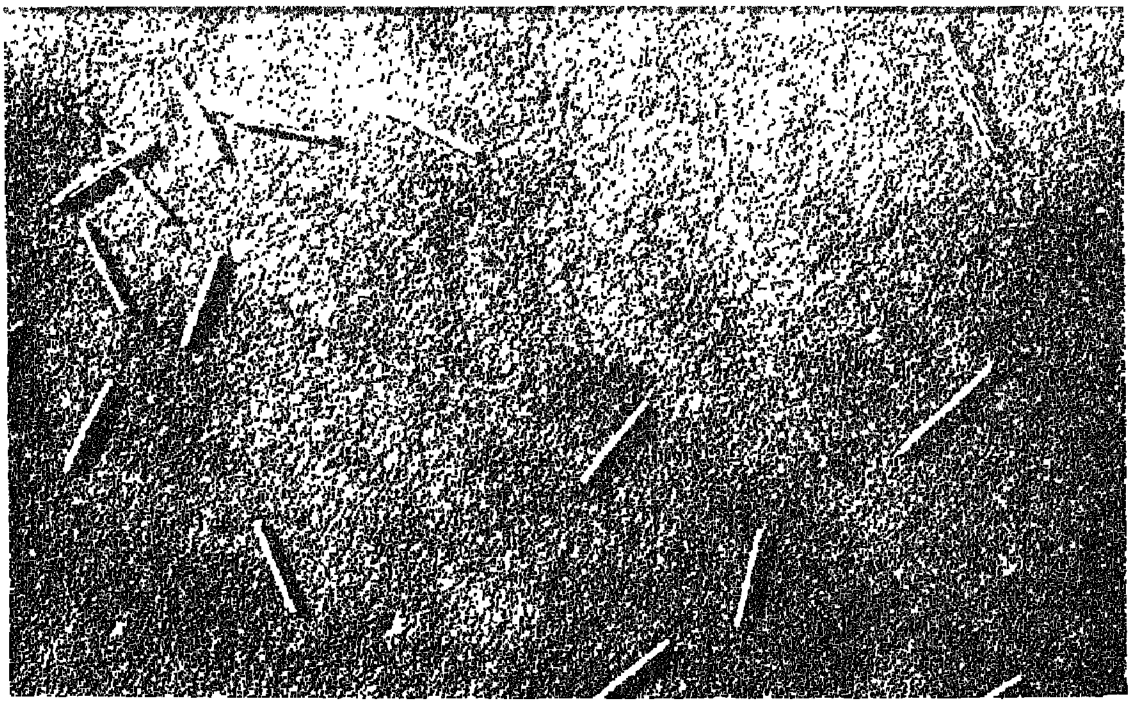

Fig. 3.8. Rod-shaped particles of a virus enlarged about 25,000 times. It is a disputed point whether viruses are living or non-living. Courtesy of R.C. Williams, Virus Laboratory, University of California, Berkeley, USA.

How Did Life Begin?

We know that all cells arise from pre-existing cells, but where did cells come from in the first place? We do not know the exact answer as yet but we shall attempt to provide an answer to this interesting and important question in Chapter 49.

SUMMARY

A simple definition of life is: 'It is the power that an organism possesses to maintain and to reproduce itself'. All organisms are made up of tiny structures called cells which contain a jelly-like substance known as protoplasm. It is composed of water, carbohydrates, amino acids, proteins, fats, nucleic acids and certain mineral substances. None of these substances is itself living but together they produce the mysterious 'life'. Nearly all living creatures can move. They all grow by changing the food they eat into new material After the intake of food, the waste products are passed out of the body by the process of excretion Living organisms are irritable, i e, they respond to stimuli Only living things can reproduce others like themselves and carry on respiration. However, viruses possess the characteristics of both living and non-living objects.

QUESTIONS

1. How does a living organism differ from:
   a. a machine,
   b. a candle flame;
   c. an iceberg?
2. Name five characteristics which differentiate living from non-living objects.
3. How can you tell whether an object is living or dead?
4. What is the difference between anabolic and katabolic processes?
5. In what way does a virus resemble a living object?
6. Most ants are completely sterile, i.e., they are incapable of reproducing themselves. Will you consider them non-living?

FURTHER READING

Asimov, I. 1954. *The Chemicals of Life.* G. Bell and Sons, Ltd., London.

Butler, J A.V. 1959. *Inside the Living Cell.* George Allen and Unwin Ltd., London.

Peattie, C. and Gordon, A 1938. *This is Living.* Dodd, Mead and Co., New York.

Pirie, N W. 1954. On Making and Recognizing Life *New Biology* No.16 pp. 41-53.

Woltere, H. 1963. *The Miracle of Life—An Exploration of Life Sources.* Souvenir Press Ltd., London.

CHAPTER 4

Cell

IF you were asked as to what is the stuff of which animals and plants are made, you will perhaps reply: animals are made of flesh and bones while plants are made of a woody material. True, but then, what are flesh and wood made of? You begin to wonder, for your eyes reveal nothing beyond this. But if you see a thin slice of flesh or wood through a microscope, you will notice that they are not just structureless, uniform material. Both of them are made of innumerable little boxes or compartments which are known as **cells.** All your body activities—movement, growth, irritability—result from a combined action of the cells composing your body parts. Cells are thus the smallest units of life; they are the building blocks of all organisms.

Historical

That plants and animals are made of cells is common knowledge today. However, before the invention of the microscope, some 300 years ago, no one knew about cells. The first person to see them was an English scientist, Robert Hooke. He prepared a crude microscope and observed all sorts of things with his newly fashioned instrument. This was around the year 1665. One day he cut a very thin slice of a bottle cork. Cork, as you might already know, is a plant material which is derived from the bark of a tree found in the Mediterranean countries. Hooke viewed the thin slice of cork with his microscope and found it to be made of a great many little boxes separated by walls (Fig. 4.1). These reminded him of the cells (compartments) of a honeycomb and he gave them the same name. Actually the piece of cork that Hooke observed was dead tissue. He observed

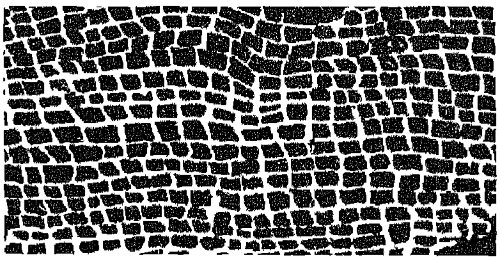

Fig. 4.1. 'Cells' as seen by Robert Hooke in a slice of cork. Courtesy of the Department of Botany, University of Delhi.

only the skeletons of the cells—just air-filled spaces surrounded by dead walls. Subsequently as scientists extended their observations to other living objects, they came to the conclusion that all plants and animals are made up of cells and that these are filled with a semi-solid, jelly-like material.

Fig. 4.2. Jacob Schleiden (1804-1881), a German botanist.

Fig 4 3. Theodor Schwann (1810-1882), a German zoologist.

From their microscopic studies of many plants and animals, they put forth the famous 'Cell Theory' (1839). Courtesy of the Department of Botany, University of Delhi

In 1831, Robert Brown, an English biologist, noted that cells also contain a dense, spherical body to which he gave the name 'areola'. This was later designated as **nucleus** (L. *nucleus*=kernel). All these facts became a part of scientific thinking in 1839 when two German biologists—Schleiden and Schwann — formulated their well-known 'Cell Theory'. This theory says (a) the cell is the unit of structure and function in all plants and animals, and (b) all cells arise from the divisions of pre-existing cells. Thus, it was only 125 years ago that the cellular organization of plants and animals was established. One exception must be noted, however. Viruses, the peculiar 'organisms' which cause several diseases, have no cellular form. You will read more about them in Chapter 19.

Some living organisms, belonging to the plant as well as the animal kingdom, are made of just one cell each. These are known as unicellular organisms. The bodies of other organisms are made up of many cells and are said to be multicellular. Some animals are composed of a very large number of cells indeed. An adult man weighing about 160 lb may have as many as sixty thousand billion cells!

Cell Structure

All cells are composed of a living substance called protoplasm. Figure 4.4 shows the generalized diagram of a cell. The protoplasm of each cell is bounded by a membrane

called the **plasma membrane**. This is a part of the cell's living material. It is very thin, less than ten thousandth of a millimetre in thickness, and can be seen only under very high magnification. It controls the movement of substances passing into or out of the cell and is unique in that it allows certain substances to pass through freely but prevents or restricts the flow of others. Such a membrane is said to be **selectively permeable.** The selectivity of the cell membrane is lost when the cell dies.

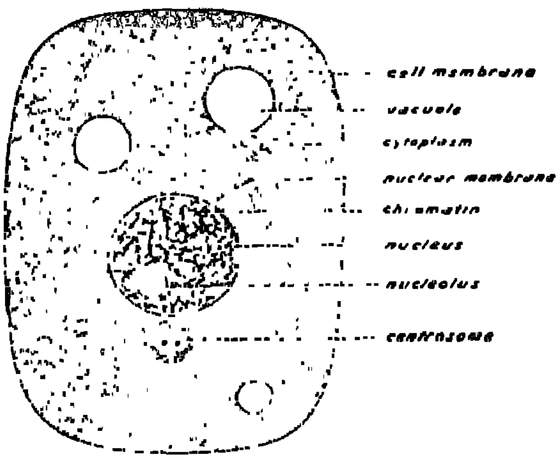

Fig. 4.4. Generalized diagram of a cell. After E B Wilson, *The Cell in Development and Heredity*, Macmillan & Co, New York, 1925

The protoplasm consists of two very well-defined parts—the **cytoplasm** and the **nucleus.** The cytoplasm is a translucent, watery or jelly-like material containing salts, fats, sugars, proteins and many other substances. It can sometimes be seen streaming about in the cell. The nucleus (plural—nuclei) is a denser spherical body placed somewhere in the cytoplasm. It is also bounded by a delicate covering called the **nuclear membrane.** Within the nucleus there is a still denser structure, the **nucleolus.** The special substance constituting the nucleus is **chromatin.** This occurs in the form of long, thread-like structures called the **chromosomes.** These threads usually occur as a confused network but, when the cell begins to divide, they can be traced as individuals. Every type of organism has a characteristic number of chromosomes in its cells. Thus, the body cells of man contain 46 chromosomes each, those of wheat 42, and so on. Very few organisms have a chromosome number exceeding 100. The chromosomes bear many, extremely minute particles, the **genes,** which control the characteristic form and growth of the organism. In other words, they are the carriers of hereditary characteristics. A dog is a dog because it has the genes of a dog handed over to it by its parents and it is a particular type of dog because it has certain genes determining that type. The nucleus controls and directs the work of the cell. If a cell be divided into two parts, one with and the other without the nucleus, the nucleated half is able to grow to the full size and reproduce but the enucleated part dies after some time (Fig. 4.5). Although the nucleus has a key role in the life of a cell, this does not mean that the rest of the

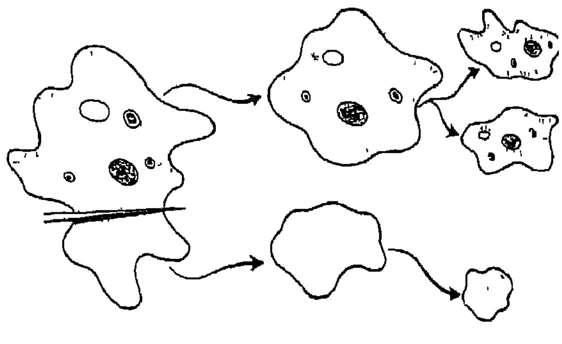

Fig. 4.5. A surgical experiment to show that the nucleus is essential for the growth and reproduction of the cell. Only the nucleated part of *Amoeba* can feed, grow and reproduce. The enucleated part may remain alive for some time but it does not feed or reproduce, and it eventually dies.

cell (cytoplasm, etc.) is unimportant. Because of the presence of the genes inside it the nucleus is the control centre of the cell functions, while the cytoplasm is the executive centre. The nucleus cannot exist without the cytoplasm just as the cytoplasm cannot exist without the nucleus.

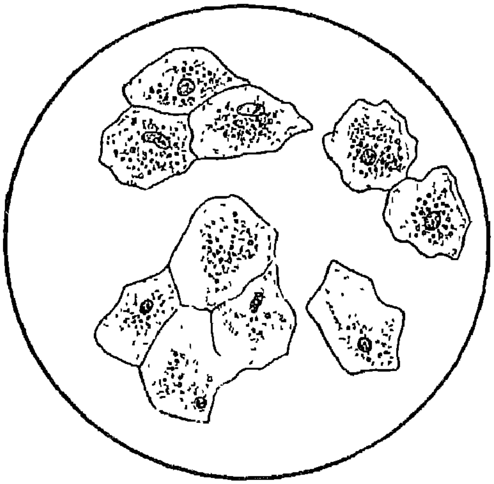

Fig. 4.6. Cells from the inner lining of the cheek. Courtesy of the Department of Botany, University of Delhi

In order to see the structure more clearly, the cells are immersed in certain dyes (stains). The nucleus generally soaks up more of such stains than the rest of the cell, thus making it appear darker than the surrounding cytoplasm. The inside lining of your cheek is a nice material to observe cells. They form a lining in which the cells fit together to form a smooth flat surface. With the blunt end of a tooth-pick scrape off some of these cells and float them in a drop of iodine solution on a clean slide. Put a cover glass and observe them under a microscope. You can easily recognize the many-sided cells with their limiting membranes, cytoplasm and nuclei (Fig. 4.6). An equally favourable material for observing cells is a thin peel from the fleshy leaf of onion (Fig. 4.7).

This is the structure of a cell as revealed by an ordinary microscope. In recent years biologists have studied cells through an electron microscope which gives 50,000 times or even more enlarged images of the objects. Figure 4.8 is a schematic diagram of cell structure as seen through an electron microscope. From this diagram and the

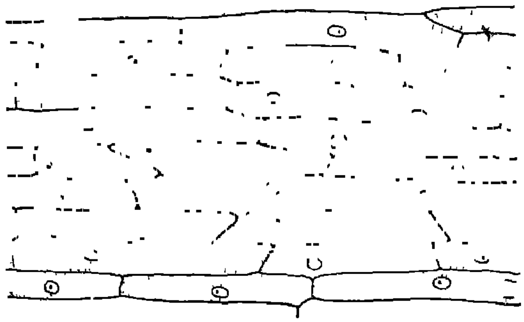

Fig. 4.7. Cells from a peeling of the onion scale. Courtesy of the Department of Botany, University of Delhi

description that follows you should not conclude that these structures are found in every cell. The diagram incorporates the principal structures found in most cells. In other words we are talking here of a 'generalized cell'.

Electron microscope studies have shown that the structure of the cell is exceedingly complex. For example, a fine network called the **endoplasmic reticulum** (Gk. *endon*=within; *plasma*=mould; L. *reticulum*=a small net) extends throughout the cytoplasm and forms a sort of 'skeleton' for the cell. The cytoplasm, which appears to be a homogeneous fluid mass under an ordinary microscope, also contains many other concrete constituents. We shall now enumerate some of these.

All cells contain hundreds of extremely small bodies called **mitochondria** (Gk. *mitos*=thread, *chondros*=grain). They may be in the form of granules, globules, rods or threads. The mitochondria are the

seat of breakdown of food materials in the cells resulting in the release of energy during respiration

In most cells there also exist numerous cup-shaped structures called the **golgi bodies** or golgi apparatus, named after their discoverer—Golgi The function of these bodies is not known with certainty but some biologists think that they are concerned with the process of secretion. Secretion means formation and giving out of a substance by the cell.

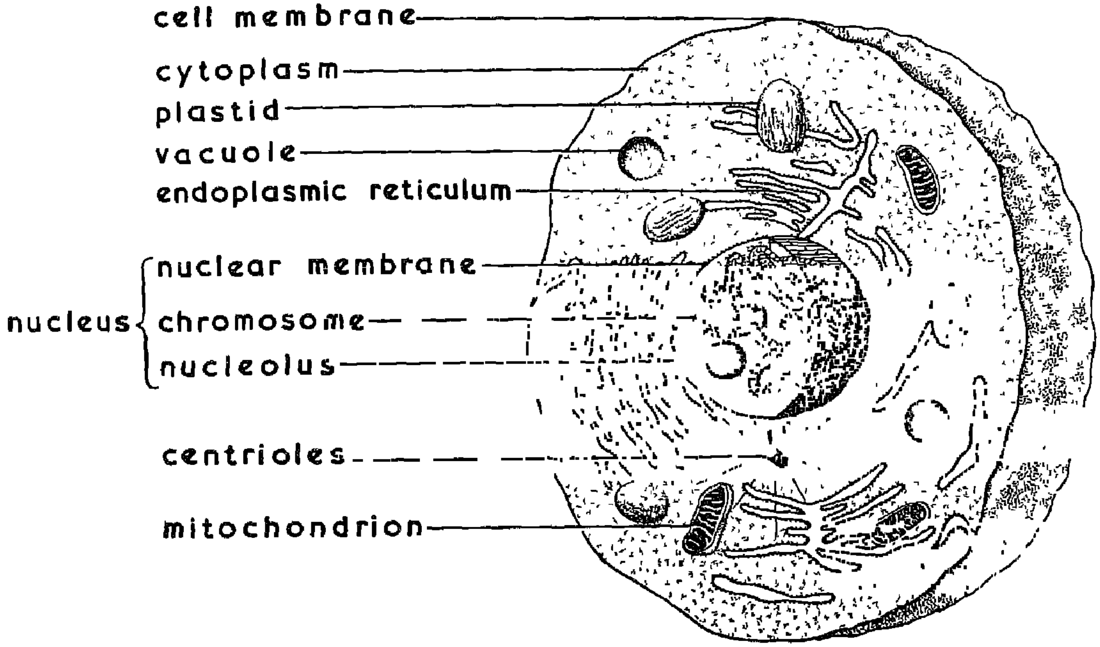

Fig. 4.8. A generalized cell as interpreted today in the light of observations made with an electron microscope. After BSCS, *Biological Science, Molecules to Man*, Houghton Mifflin Company, Boston, 1963

Some other extremely small particles called the **microsomes** or **ribosomes** are also present in the cytoplasm. These are important because protein synthesis takes place on their surface.

In the cytoplasm one may also find one or more small, balloon-like spaces filled with a watery, non-cytoplasmic fluid. These areas are called **vacuoles.** The watery fluid of the vacuoles is called **cell sap** and is separated from the general cytoplasm by a delicate membrane, the **tonoplast.**

Animal *versus* Plant Cells

The features so far mentioned are shared by both plant and animal cells. However, the cells of plants and animals have certain special characteristics of their own (Fig. 4 9). One of these is that plant cells are surrounded by a definite, rigid, non-living, cell wall made of a substance called **cellulose**—the same material of which your cotton shirt is made. The plasma membrane lies inner to this wall. To demonstrate the identity of the plasma

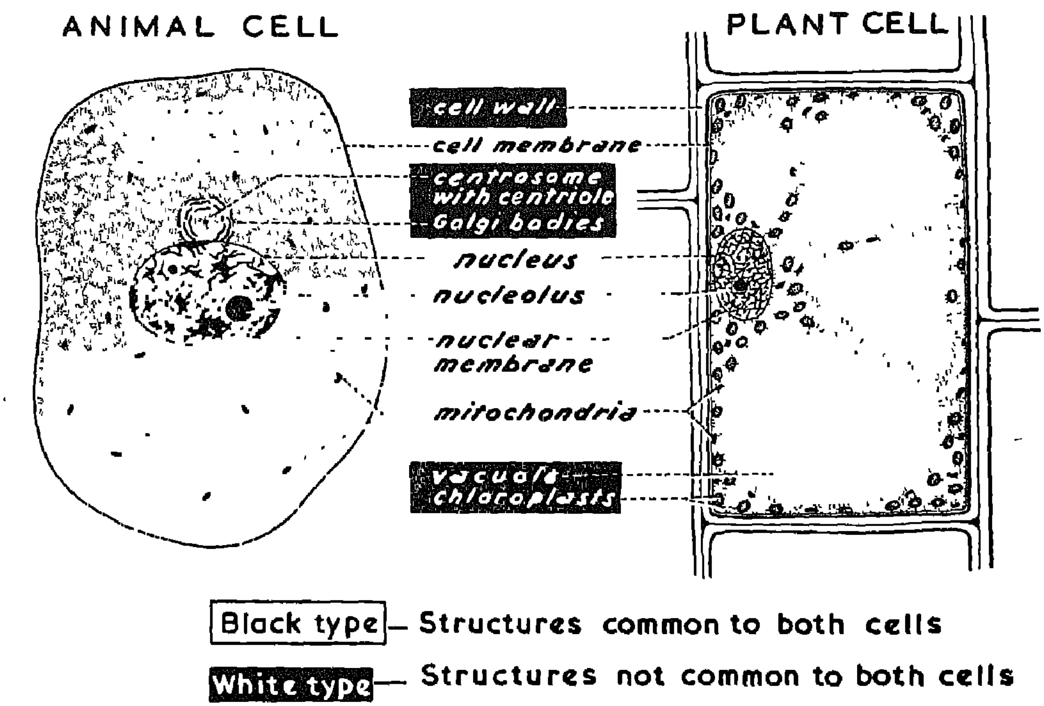

Fig. 4.9. Comparison of a generalized animal and plant cell. Although in this figure golgi bodies have been shown in the animal cell alone, recent investigations indicate that they are present in some plant cells also. Adapted from BSCS, *Biological Science—An Inquiry into Life*, Harcourt, Brace & World, Inc , New York, 1963.

membrane as distinct from the cell wall, place a group of cells in a concentrated solution of sugar. The cytoplasm with its plasma membrane will shrink inside while the cell wall remains in position Most animal cells, on the other hand, are covered only by the plasma membranes. In the cytoplasm of animal cells there is another special structure, the **centrosome,** situated close to the nucleus. The centrosome is a somewhat clear area in which a pair of granules, the **centrioles,** can be seen. When a nucleus begins to divide, the centrioles develop a number of radiating threads or **rays.** The whole structure (centriole and rays) is then called an **aster.** More will be said about it in the next chapter.

Plant cells usually show a number of dense bodies, the **plastids,** in the cytoplasm. The most conspicuous of these are the **chloroplasts,** containing a green pigment called **chlorophyll.** Some plastids may contain other colouring matter and are termed as **chromoplasts,** and still others, called **leucoplasts,** contain no pigment at all. Finally, plant and animal cells differ in that the vacuoles are smaller and less numerous in animal cells than in mature plant cells.

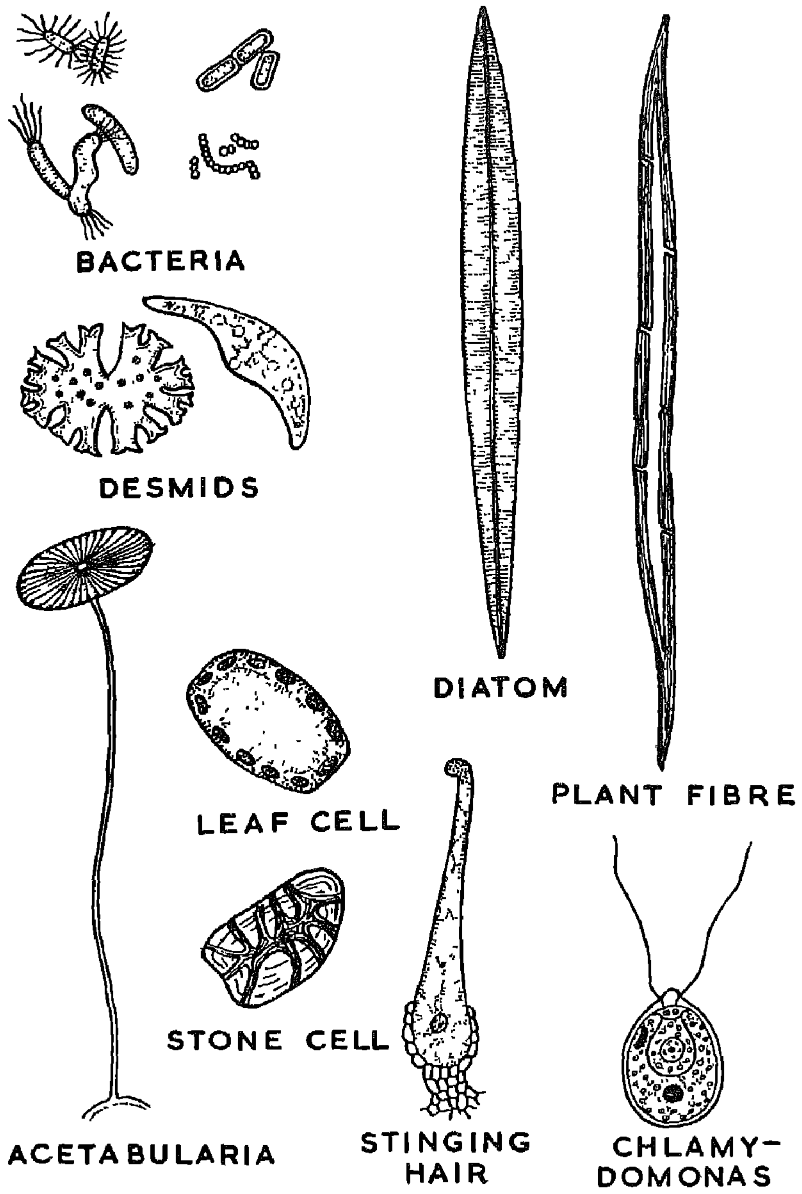

Fig. 4.10. Shapes of plant cells. Bacterial cells may be spherical, rod-like or spiral. Desmids and diatoms are unicellular algae. Fibres occur in strands along the stems of many plants such as jute. Leaf cells contain green bodies called chloroplasts by means of which they synthesize food material. *Acetabularia* **is a unique alga, the entire plant being made of just one cell. Stone cells are dead cells occurring in the gritty portions of peach and apple fruits. Stinging hair cells occur on the stems of stinging nettles.** *Chlamydomonas* **is a unicellular green alga.** After C P Swanson, *The Cell*. Foundations of Modern Biology Series, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1958.

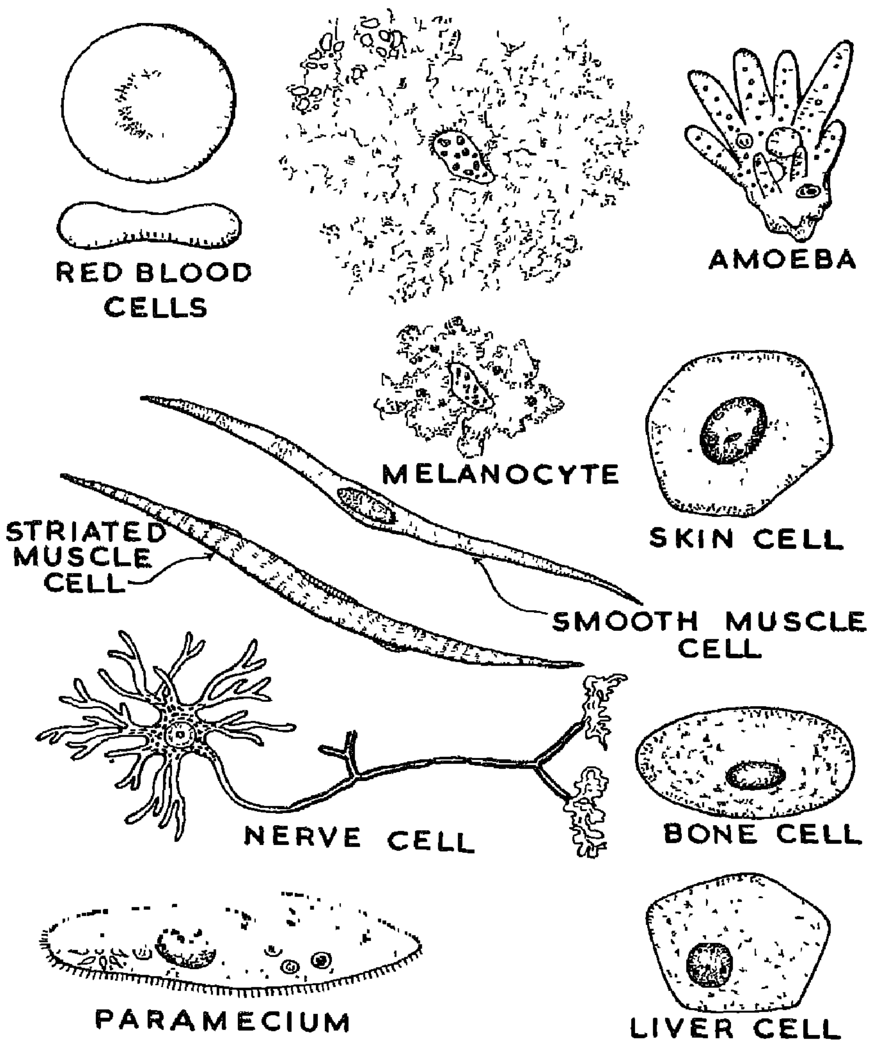

Fig. 4.11. Shapes of animal cells. Human red blood cells are drawn in front and side views. Melanocytes (pigment containing cells) are shown in expanded and contracted conditions. *Amoeba* **is a unicellular animal that changes its shape almost every moment. Skin cells look like tiles in a floor. Elongated muscle cells joined together into bundles form the so-called flesh or muscles. Nerve cells with their long cable-like processes form the nerves which transmit stimuli. Bone cells occur in the hard framework of bones. Liver cells, though similar to the skin cells in shape, perform an entirely different function.** *Paramecium* **is a unicellular slipper-shaped animal found in pond water.** After C P Swanson, *The Cell*· Foundations of Modern Biology Series, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1958

Cell Size and Shape

The cells you have so far seen are a few of the many types that you will come across in your stndy of plants and animals. Most of these are too small to be seen without a microscope though a few are quite large and can be seen with the naked eye. The yolk of a hen's egg is a single cell. The largest cell known is the yolk of the egg of an ostrich which may be as much as 7 cm across. The nerve cells in your body have 'tails' which are over a metre long though their diameter is very small. The individual fibres of Manila hemp are over a metre in length. The smallest cells are those of bacteria. These are measured in microns, one micron (written as μ) being one-thousandth of a millimetre.

The shapes of cells are also very variable. Figures 4.10 and 4.11 illustrate some of the many kinds of cells of which plants and animals are built. Single-celled organisms, freely swimming in water, generally tend to have a spherical form though this is not always so. For example, *Paramecium*, a unicellular animal, has the shape of a slipper.

Composition of Protoplasm

Every living organism must perform a number of life processes such as metabolism, movement, reproduction, and the like. This is as true of a unicellular organism like a bacterium as of a multicellular one like man. This means that every cell is actually an exceedingly complex factory in which a large number of chemical processes are taking place simultaneously.

Since protoplasm is the unique living stuff, you might think that it contains some unusual elements which are completely absent from non-living objects. This is, however, not the case. Protoplasm is made up of the same elements that occur in lifeless things such as stones, sand, air and water. But out of about 100 elements found in our earth, only about 25 enter into the composition of living material. Further, 99 per cent of the protoplasm by weight is composed of just four elements—carbon, hydrogen, nitrogen and oxygen. There are no special elements that are present only in the protoplasm. It is, however, not the elements but the compounds formed from them which make protoplasm different. There are thousands of compounds which chemists have recognized in protoplasm. Of these the most important are water, proteins, fats, carbohydrates, nucleic acids and mineral salts. You will read more about them in Chapter 38.

Fig. 4.12. A plant tissue culture. Cell masses grown on synthetic medium are used to study the reactions of cells when they are fed with certain substances or subjected to other treatments. Such cultures are gaining great importance in medical research, especially that concerned with cancer and effects of atomic radiations. Courtesy of the Department of Botany, University of Delhi.

Cell Cultures or Tissue Cultures

In order to study the working of the complex machinery of a particular type of cell, biologists often isolate the cells from an organism's body and grow them artificially (Fig. 4.12) on a nutritive medium in a flask or test tube. This technique is known as **tissue culture** or **cell culture.** In one such culture, cells from the heart of a chicken were kept growing for a period of 27 years, although the source chicken must have lived its usual life of only 20 years. Such cultures are also useful in studying the reactions of cells when they are fed with certain poisons, or infected with germs, or subjected to X-rays.

SUMMARY

Plants and animals are made up of tiny building units called cells. In some organisms a single cell makes the entire body, others are made up of a large number of cells, going up to many billions.

Although there is a wide variation in the size and the shape of cells, the living substance or protoplasm in nearly all cells shows three main parts—nucleus, cytoplasm and cell membrane. The nucleus directs and controls the activities of the cell. The cytoplasm is the seat of all these activities. The cell membrane regulates the flow of substances into and out of the cell.

Studies with the electron microscope have revealed the detailed structure of mitochondria, ribosomes, golgi bodies, centrioles and other granules. Each of these entities has a special function to perform. Plant cells differ from animal cells in having cellulose walls and conspicuous vacuoles However, they lack the centrioles which are so characteristic of most animal cells.

The chemical elements composing the protoplasm are the same as those found in non-living things. The elements are combined into many types of compounds. The carbohydrates, proteins, fats, nucleic acids, salts and water are the most important compounds found in protoplasm.

Cell cultures can be started from a group of cells taken from any part of an organism. These cultures have proved very useful in studying the physiology of cells.

QUESTIONS

1. What is the difference between the meaning of the word 'cell' as used by Hooke and by present day biologists?
2. Why is the cell regarded as the basic unit of structure and function of all life?

3. What is the function of (a) mitochondria; (b) ribosomes; and (c) cell membranes?

4. Which of the following are found (1) exclusively in plant cells; (2) exclusively in animal cells, (3) in both?

   (a) nuclei, (b) nucleoli, (c) chloroplasts, (d) chromosomes, (e) centrioles, (f) mitochondria, (g) cell walls, (h) golgi bodies, (i) ribosomes, (j) plasma membranes.

5. Supposing you examined a thin slice of plant tissue and found some cells without nuclei. How would you account for this?

6. What is the difference between a cell wall and a cell membrane?

7. List three elements in the order of their abundance in the protoplasm.

FURTHER READING

ANONYMOUS 1962. All Living Things are Made of Cells. *Understanding Science* Vol.1 No.1 pp.10-11.

ANONYMOUS 1962. The Way Living Cells are Constructed for the Work They do. *Understanding Science* Vol. 1 No. 5 pp. 72-74.

ANONYMOUS 1963. Cells and Their Structure. *Understanding Science* Vol.5 No.49 pp.769-771.

GAY, HELEN 1960. Nuclear Control of the Cell. *Scientific American* Vol.202 No.1 pp.126-136.

HOFFMAN, J.G. 1957. *The Life and Death of Cells.* Doubleday, New York.

SCHMITT, F.O. 1957. Giant Molecules in Cells and Tissues. *Scientific American* Vol.197 No.3 pp 204-216.

SIEKEVITZ, P. 1957. Powerhouse of the Cell. (Mitochondria and Respiration.) *Scientific American* Vol.197 No.1 pp.131-140.

SWANSON, C P. 1958. *The Cell*: Foundations of Modern Biology Series. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

CHAPTER 5

Cell Division

YOUR body consists of billions of cells. Even when you were born, it had millions of them. All these cells came from a single cell, the fertilized egg. It divided into two, then into four, then into eight and so on. To study cell division let us first recall to our minds the structure of a cell.

A cell is filled with the living matter or protoplasm. The protoplasm is divided into two major parts: the cytoplasm and the nucleus. When the cell is not dividing, its nucleus is said to be in the so-called **resting state** (Fig 5 1A). The nuclei of all cells contain rod-like structures known as chromosomes. The number of chromosomes in any given type of organism is constant. Thus, cells of human beings have 46 chromosomes; of dog 78; of cat 38; of garden pea 14; of onion 16 and so on. In the resting nucleus the chromosomes cannot be seen individually. Instead, they appear as a jumbled chromatin network. In animal cells there is also a centriole outside the nucleus.

Cell division consists of two distinct processes: **nuclear division** or **mitosis,** and **cytokinesis** which involves the division of the remainder of the cell and the formation of a new cell membrane or cell wall. Walther Flemming, a German biologist of the later part of the 19th century was the first to study cell division. He stained the cells in a suitable dye so that the nucleus stood out from the rest of the cell and could be more easily studied. He wrote an account of his observations in the year 1880. He stated that in a dividing cell the nucleus passes through an orderly series of changes which he collectively named as mitosis. The process is a continuous one, but for convenience of description it is divided into different steps or phases, which are essentially the same for plant and animal cells (Fig. 5.2).

Division of the Nucleus—Mitosis

When the cell is about to divide, several changes take place in the appearance of the nucleus (Fig. 5.1 B-D). The fine network is transformed into a definite number of long, delicate threads—the chromosomes, which gradually become more distinct. Since this is the first and the most obvious change associated with nuclear division, the name mitosis (Gk. *mitos*=a thread) was used to describe the entire process. Four progressive stages of mitosis can be recognized.

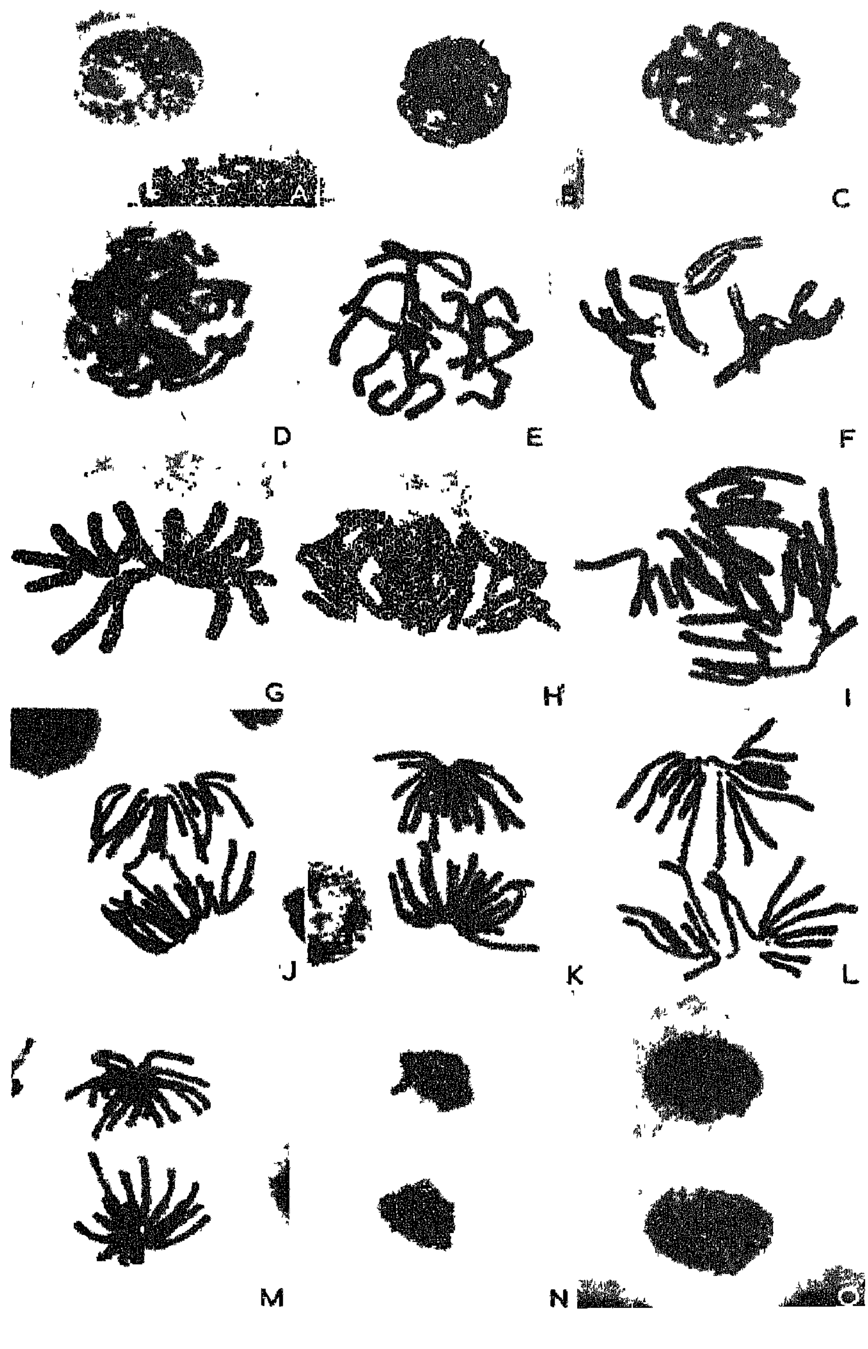

Fig. 5.1. **Stages of mitosis in the root tip cells of** *Paris polyphylla*. **A. Interphase nucleus. B, C and D. Early prophase. E. Late prophase. F. Metaphase chromosomes showing duplication (chromatid formation). G. Metaphase. H. Early anaphase. I-L. Anaphasic separation of sister chromosomes. Note the I-J- or V-shaped chromosomes. M. Early telophase. N. Late telophase. O. Cytokinesis. The two daughter nuclei have reorganized, and cell plate has been laid.** Courtesy of Virendra Kumar, Delhi College.

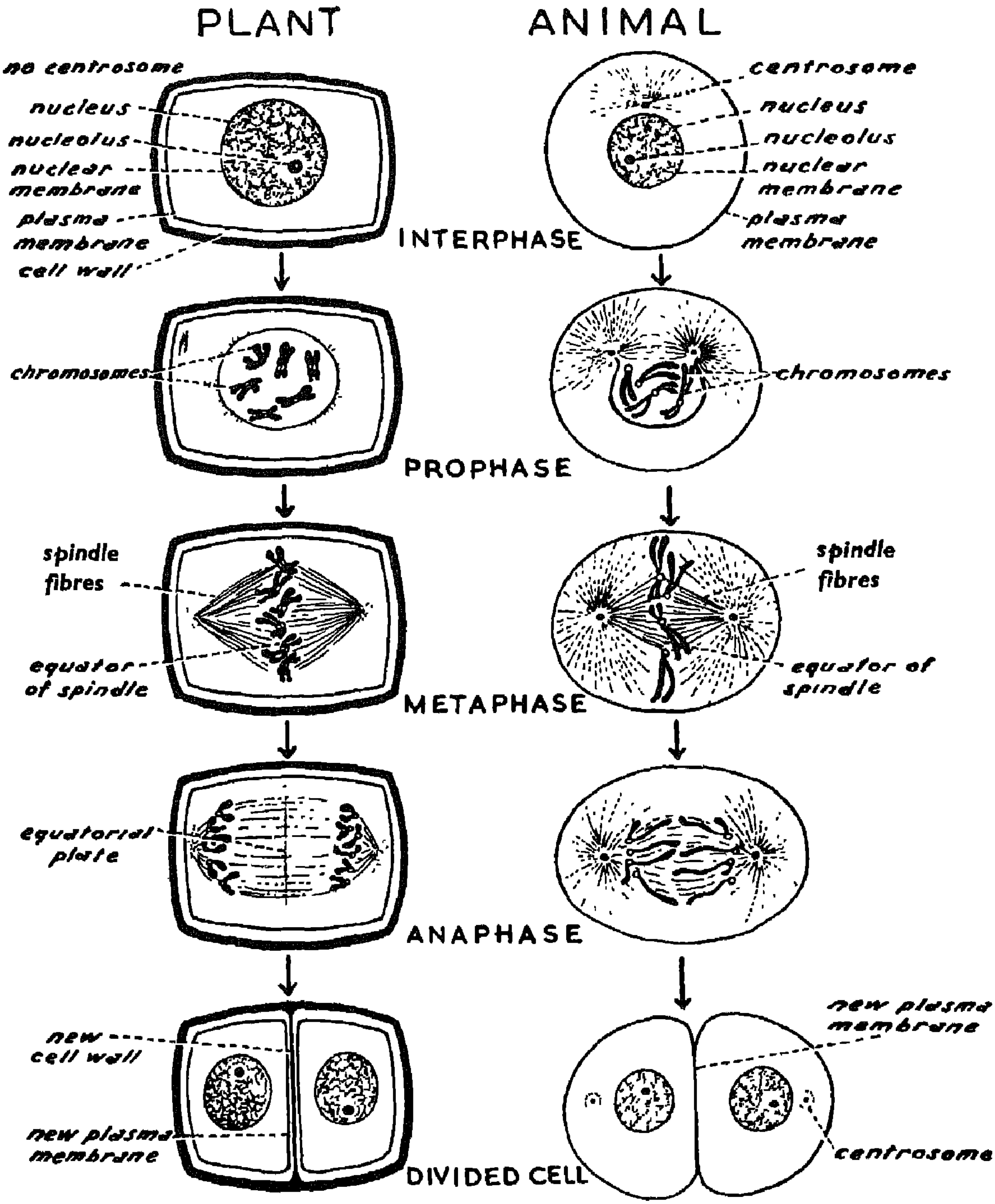

Fig. 5.2. Diagram of cell division in plant and animal cells. From J.W. Mavor, *General Biology*, Macmillan Co., New York, 1959.

Prophase. This stage begins with the transformation of the chromatin network into a definite number of chromosomes Each chromosome now shows two slender threads called **chromatids** which are connected together by a small area, the **centromere.** Hence there are twice as many chromatids as there are chromosomes The various chromosomes formed in a given cell usually have their distinctive shapes—a hook, rod or dot There are generally two chromosomes of each shape; that is, the chromosomes always exist in pairs. Hence we frequently say that the organism has a certain number of pairs of chromosomes. Man has 23 pairs, dog has 39 and so on.

A number of other changes also occur at this stage. The nucleoli gradually become less conspicuous and eventually disappear. The centriole situated outside the nuclear membrane divides into two. These move apart and take up a position on opposite sides (poles) of the nucleus. The cytoplasm surrounding the centrioles forms radiating threads. The centriole with these tiny rays is known as an **aster** (Fig. 5 2). However, asters are absent in the cells of plants.

Metaphase. The next stage, called metaphase, begins with the disappearance of the nuclear membrane By this time the chromosomes have become quite distinct (Fig. 5.1 F) and exhibit their characteristic shape and size. They lie in the central region of the nucleus The cytoplasm surrounding the chromosomes forms long rows of fibres arranged in the form of a spindle The chromosomes come to lie in the centre of the spindle on the so-called equatorial plate or the metaphase plate. Some spindle fibres are attached to the centromere of each chromosome. The position of the centromeres on the chromosomes varies and depending on this the chromosomes are J,V,U or I-shaped (Fig. 5.3).

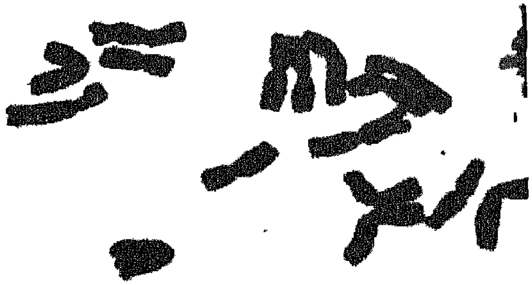

Fig. 5.3. Diploid chromosome complement in the root tip cell of *Allium strachyi* The spindle in this preparation was dissolved by a special chemical treatment to facilitate better spreading of chromosomes. Courtesy of Virendra Kumar, Delhi College.

Anaphase. During anaphase the centromere of each chromosome divides into two and the sister chromatids move apart. Probably the contraction of spindle fibres helps in the separation of chromatids. By late anaphase, each pole has received one set of chromatids which now correspond to chromosomes (Fig 5.1 H-L).

Telophase. In the final stage or telophase the nuclei of the daughter cells are once again organized from the chromosomes at each pole. Each nucleus has the same number and type of chromosomes as the parent cell. This is because each chromosome, during nuclear division, added to itself or reproduced a chromatid like the one initially present in it. At the commencement of the interphase these two daughter cells are smaller than the parent cell, but they are identical as regards their chromosomal material. Gradually, they increase to full size (Fig. 5.1 M-N).

Division of Cytoplasm—Cytokinesis

This is a process by which the cytoplasm of a cell is separated into more or less two

equal parts. In animal cells cytokinesis is accomplished by mere constriction. This begins during the anaphase of mitosis and is completed by the close of telophase. Because of the presence of rigid cellulose walls in plant cells, cytokinesis by constriction is not possible. Cytokinesis in a plant cell begins by the formation of a cell plate in the middle of the cell during late anaphase. The plate now extends in circumference till it meets the wall of the parent cell. A new cellulose wall is now laid down on both surfaces of the cell plate which becomes the middle lamella between the two cells. In the meantime the new nuclei have been organized and the process of cell division is completed.

Significance of Mitosis

Since the chromosomes of a dividing cell undergo doubling and since the two chromatids of each chromosome move to the opposite poles, the two daughter cells receive the same number and the same kind of chromosomes as were contained in the parent cells. The genes, which determine the hereditary characters are located on the chromosomes, and therefore, each cell comes to have the same potentialities as the parent cell. A division of the nucleus which results in two similar nuclei, is said to be equational. Although the cells have the same genetic material and are indeed similar when first formed, they may become different in order to carry on their specific functions. This phenomenon of 'becoming different' is known as **cell differentiation** and will be taken up in greater detail in the next chapter.

SUMMARY

The bodies of multicellular animals and plants consist of billions of cells, all of which have been derived from one parent cell—the fertilized egg or the zygote. The mechanism of division is such that the daughter cells come to have the same potentialities as the parent cell.

Cell division involves two processes—mitosis and cytokinesis Mitosis is divisible into four stages — prophase, metaphase, anaphase and telophase. During prophase each chromosome adds to itself (duplicates) another chromatid exactly similar to the first. The two chromatids are held together with the help of a centromere. Simultaneously the nucleolus disappears and the centriole (in animal cells) divides into two.

In metaphase the nuclear membrane disappears and a spindle of dense fibres appears in the cytoplasm. The chromosomes become arranged on the 'equatorial plate' of the spindle.

During anaphase the centromeres divide and the chromatids of each chromosome move towards the opposite poles.

In the final stage or telophase the two sets of chromatids are once again organized into two nuclei. Each daughter nucleus receives the same number and type of chromosomes as its parent nucleus.

During cytokinesis the parent cell divides to form two daughter cells. In animals, this is achieved merely by constriction. In plants, on the other hand, a plate is first laid down across the cell. Cellulose is then deposited on two sides of the plate and the original cell is partitioned into two by a distinct cell wall.

QUESTIONS

1. Fill in the blanks:
   a. The division of the centromere occurs during.......
   b. The spindle is formed in the.... stage.
   c. The chromosomes become double during the ..... stage.
   d. The chromatids start moving towards the poles of the spindle in the ....stage.
2. How does the process of mitosis differ in animal and plant cells?
3. Mitosis is called 'equational division' by some authors. What do you understand by this statement?
4. What is the significance of this equational division?
5. Where would you look for active cell divisions in a plant? In an animal?
6. Define the terms chromatid, cytokinesis, centriole, interphase (or resting phase).

FURTHER READING

ANONYMOUS 1963. The Reproduction of the Cell. *Understanding Science* Vol.5 No 51 pp.812-814.

GERARD, R. W. 1940. *Unresting Cells.* Harper and Brothers, Publishers, New York.

MAZIA, D. 1953. Cell Division. *Scientific American* Vol 189 No 2 pp 53-63.

MAZIA, D. 1961. How Cells Divide. *Scientific American* Vol.205 No.3 pp. 100–120.

CHAPTER 6

Cell Differentiation

SOME plants and animals are made up of just one cell (unicellular) while others consist of many cells (multicellular). In a unicellular organism, the single cell performs all the life functions like nutrition, respiration, excretion of wastes, and reproduction In a multicellular organism, however, the cells play more specialized parts in its life activities The cells composing your brain, for instance, enable you to think, those making your tongue help you to taste things, and those forming muscles make possible the movement of your limbs The cells comprising the different parts of the body not only perform different functions but also differ, from one part to another, in size, shape and other features. The phenomenon by which they assume different forms and functions is known as cell differentiation.

You learnt in an earlier chapter that all new cells originate from pre-existing cells. As an example, the fertilized egg, which is just a tiny speck of apparently formless protoplasm, eventually becomes a human being—with eyes, ears, limbs, heart and brain—composed of billions of cells (Fig. 6 1). You also learnt that the mechanism of cell division (mitosis) is such that the daughter cells have similar characteristics. How is it then, that in multicellular organisms certain cells become different from certain others? This paradox of cell differentiation is one of the big puzzles of biology. A newly formed cell has the capacity to develop into any type, a muscle cell, a hair cell, a bone cell and so on. As it grows, some unknown influence determines which type it will become.

A group of cells, which are similar in structure and perform the same function, form a **tissue.** The plant and animal body consists of a variety of tissues each of which performs a specific function.

PLANT TISSUES

In plants there are two main types of tissues: (a) **meristematic tissues** which consist of undifferentiated, actively dividing cells, and (b) **permanent tissues** comprising cells which have become differentiated to perform a particular function and have lost their ability to divide.

Meristematic Tissues

Meristematic tissues are usually found at the tips of stems and roots (Fig. 6.2 A, B) where the chief growth in length occurs. Meristematic cells are small and possess

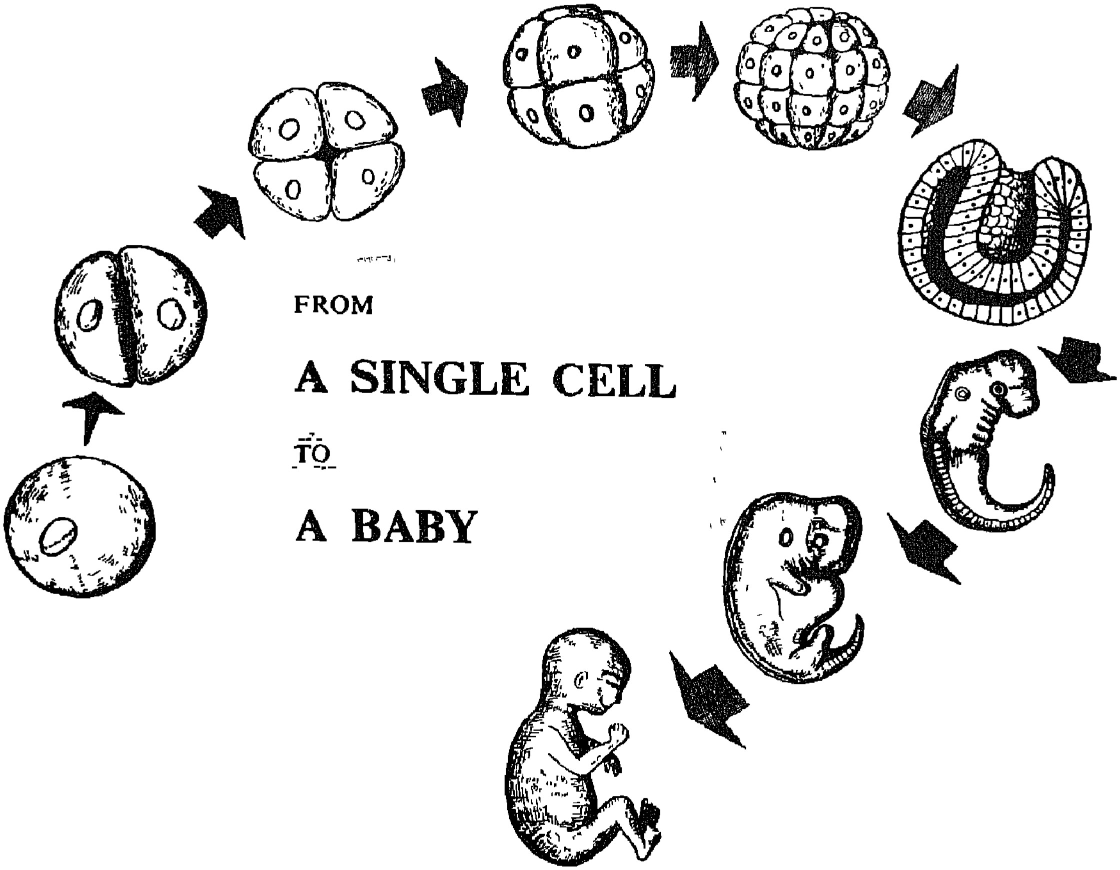

Fig. 6.1. From a single cell to a baby. The phenomenon of differentiation is one of the major unsolved problems of biology.

thin walls. They are almost completely filled with cytoplasm and have large, conspicuous nuclei. They divide repeatedly and produce new cells which later differentiate to form the specialized cells of the plant body.

Permanent Tissues

The permanent tissues form the bulk of a plant body. The cells composing these tissues have assumed their final shape and show no division On the basis of their functions in the plant body they are classified into several types which are treated below.

The **fundamental tissue** or **parenchyma** (Fig 6 3) consists of masses of cells without much specialization in structure or function. All soft parts of the plant are composed of parenchyma. The cells may be spherical, columnar or irregular in shape. They usually have thin walls and large vacuoles. In leaves and tender stems, these cells contain the green pigment, chlorophyll, and

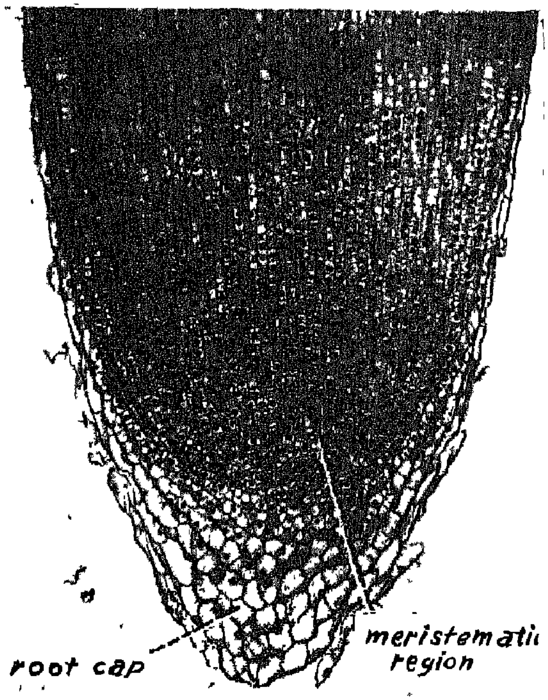

Fig. 6.2 A. Longitudinal section of the apex of a root. Note the densely cytoplasmic cells some of which are in the process of division. Courtesy of the Department of Botany, University of Delhi.

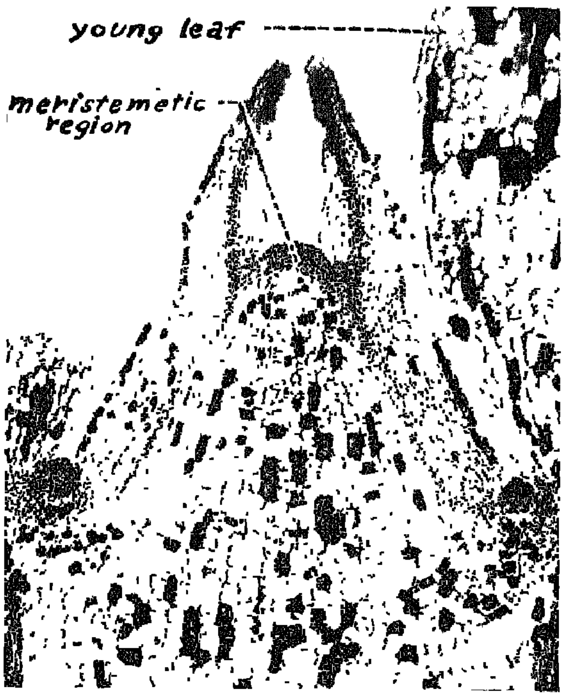

Fig. 6.2 B. Longitudinal section of stem apex. Courtesy of Mridul Wadhi, Department of Botany, University of Delhi

serve as centres of food synthesis. In other parts of the plant they function as storehouses for food and water. The cells in a potato tuber, for instance, are parenchymatous cells filled with starch.

Several types of cells give mechanical support to the organ in which they occur. A common feature of all supporting cells is that their walls are thickened so as to stand various stresses and strains. The sub-epidermal layers of stems and leaf stalks have elongated cells that are irregularly thickened at the corners due to an extra deposition of cellulose. A tissue made of such cells is known as **collenchyma** (Fig. 6 4). It makes the stems flexible so that they can stand bending or swaying by wind or passing animals. Another type of strengthening tissue is the **sclerenchyma** (Fig. 6 5). Its cells have very thick walls due to the deposition of a waterproof material called **lignin** and are usually dead at maturity. The thickening on the wall is often so heavy that it fills the entire cell cavity. The hard grit in a pear fruit (Fig. 6.5 A), the brittle coats of seeds, the hard walls of nuts and a considerable part of the wood are all made of sclerenchymatous cells. When these cells are greatly elongated and pointed at both the ends, they are referred to as **fibres** (Fig. 6.5 B, C). On the other hand, if they are nearly as long as broad, they are called **sclereids.** Sclerenchyma cells usually

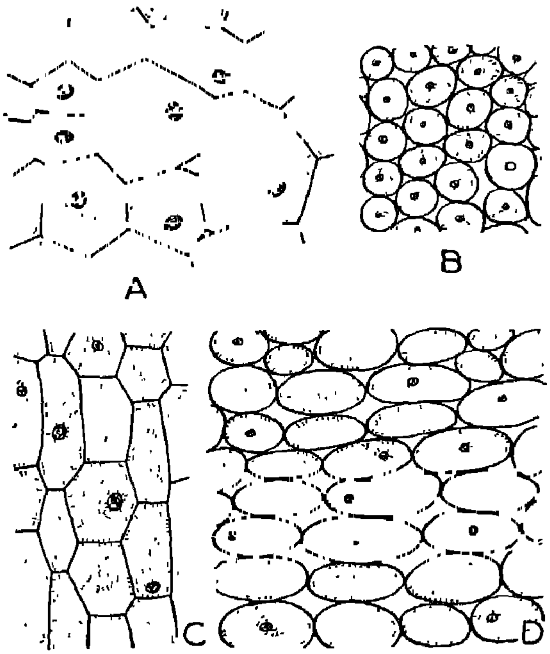

Fig. 6.3. **Parenchyma cells. A and B. Cross sections. C and D. Longitudinal sections.** Courtesy of the Department of Botany, University of Delhi.

occur in continuous masses or patches and are packed into bundles by a cementing material. Jute and coir are obtained from thick bundles of fibres.

The surface of all soft plant parts is covered over by a single layer of cells, the **epidermis** (Fig. 6.6). This protects the plant from undue loss of water and from minor external injury. The epidermal cells are of various shapes and secrete a waxy substance called **cutin.** This forms a thin, waterproof layer, the **cuticle,** on the outer walls of the cells (Fig. 6.6 A). In some plants, the epidermal cells bear outgrowths in the form of hairs. The density of hairs and their structure and function vary from plant to plant. In the stinging plant, for instance, the hairs contain formic acid and 'sting' passing animals if they happen to touch them. In plants growing in dry places, the thick growth of epidermal hairs serves to reduce the evaporation of water. The epidermal tissue is not continuous but has a large number of pores called **stomata** (Fig. 6.6 B). Each stoma is flanked by two special cells known as the **guard cells** which are unique in that they can cause the opening or closing of the stoma. The exchange of gases (such as oxygen

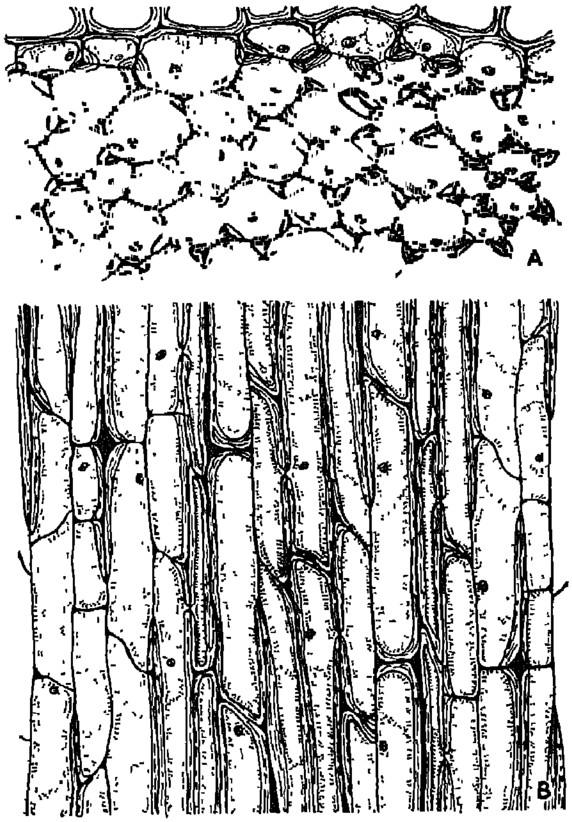

Fig. 6.4. **Collenchyma cells. A. Cross section. B. Longitudinal section. A,** after Katherine Esau, *Plant Anatomy*, John Wiley & Sons, Inc., New York, 1953. **B,** after A J. Eames and L.H. MacDaniels, *An Introduction to Plant Anatomy*, McGraw-Hill Book Company, Inc., New York, 1947.

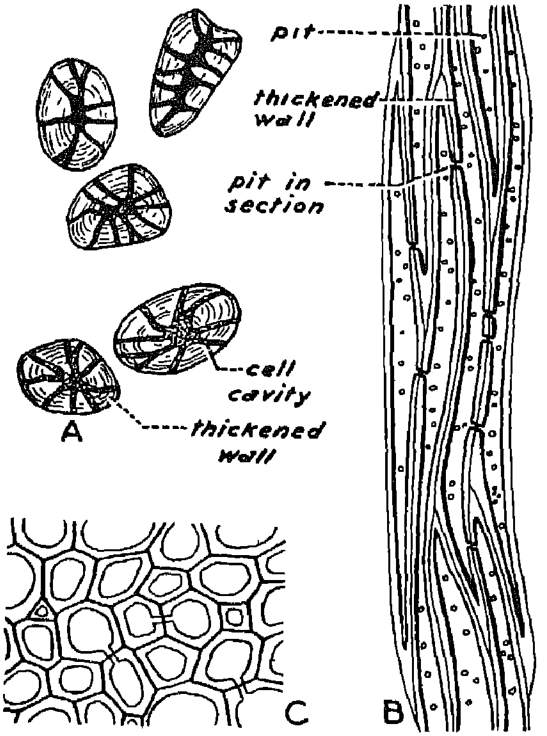

Fig. 6.5. Sclerenchyma. A. Stone cells from the gritty portion of a pear fruit. B and C. Longitudinal and transverse sections of fibres. From J. B. Hill, L O. Overholts, H. W. Popp and A. R. Grove, Jr., *Botany, A Textbook for Colleges*, McGraw-Hill Book Company, Inc., New York, 1960.

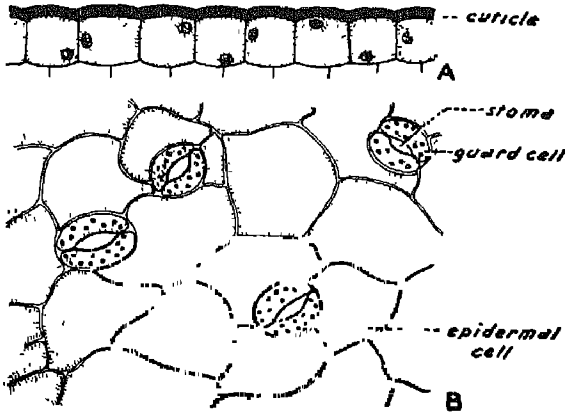

Fig. 6.6. The epidermal tissue. A. Epidermis in transverse section; note the thick cuticle. B. Surface view of epidermis showing stomata. Courtesy of the Department of Botany, University of Delhi.

and carbon dioxide) takes place mostly through these pores.

The trunks of woody trees are protected by another type of tissue called **periderm.** It is several layers thick. Its cells are cubical (Fig. 6.7) and have walls coated with a waterproof substance called **suberin.** The bark that peels off on tree trunks in the form of flakes is a part of the periderm tissue. The bottle cork of commerce also comes from the periderm of a tree.

The **conducting tissue**, as the name suggests, conducts water and food materials. It is composed of many types of cells. The part of the conducting tissue which transports water is known as **xylem**; while that concerned with the translocation of food is termed **phloem.** The main conducting elements in the phloem are the **sieve tubes** (Fig. 6.8). These are made up of elongated, cylindrical cells arranged in vertical rows. The end wall (the cross wall) of each sieve tube member is studded with fine pores, like those in a sieve. . This is therefore

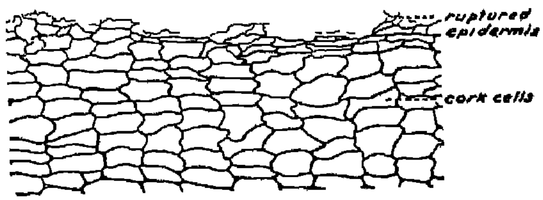

Fig. 6 7. A part of the periderm tissue (cork) in transverse section. The cell walls are heavily coated with a waterproof substance called suberin. By the time this tissue is formed, the overlying epidermis becomes ruptured. Courtesy of the Department of Botany, University of Delhi

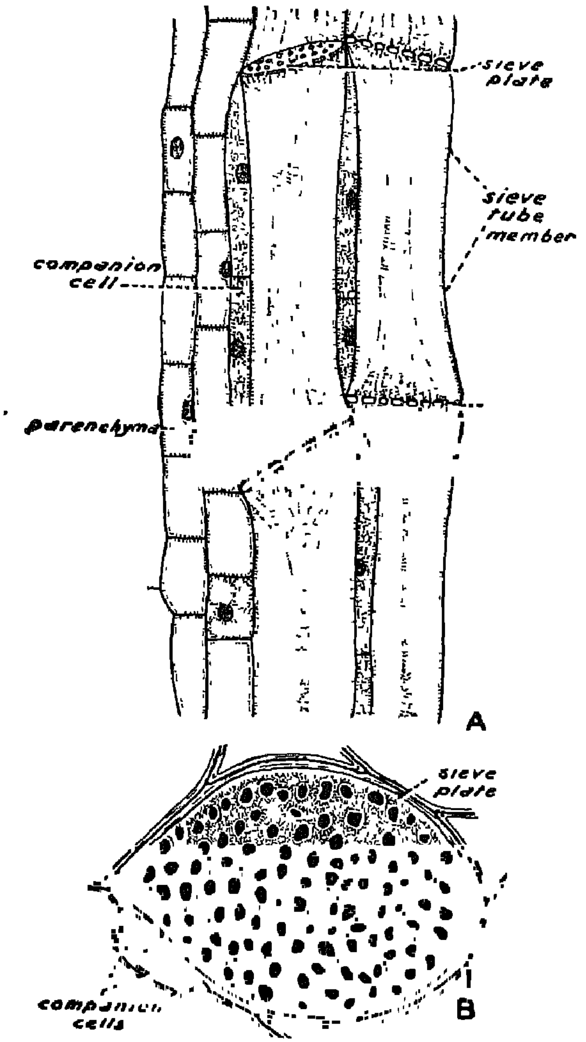

Fig. 6.8. A and B. Longitudinal and cross sections through phloem. A, after J.B. Hill, L.O Overholts, H W Popp and A R. Grove, Jr., *Botany, A Textbook for Colleges*, McGraw-Hill Book Company, Inc , New York, 1960. **B,** after Katherine Esau, *Plant Anatomy*, John Wiley & Sons, Inc., New York, 1953.

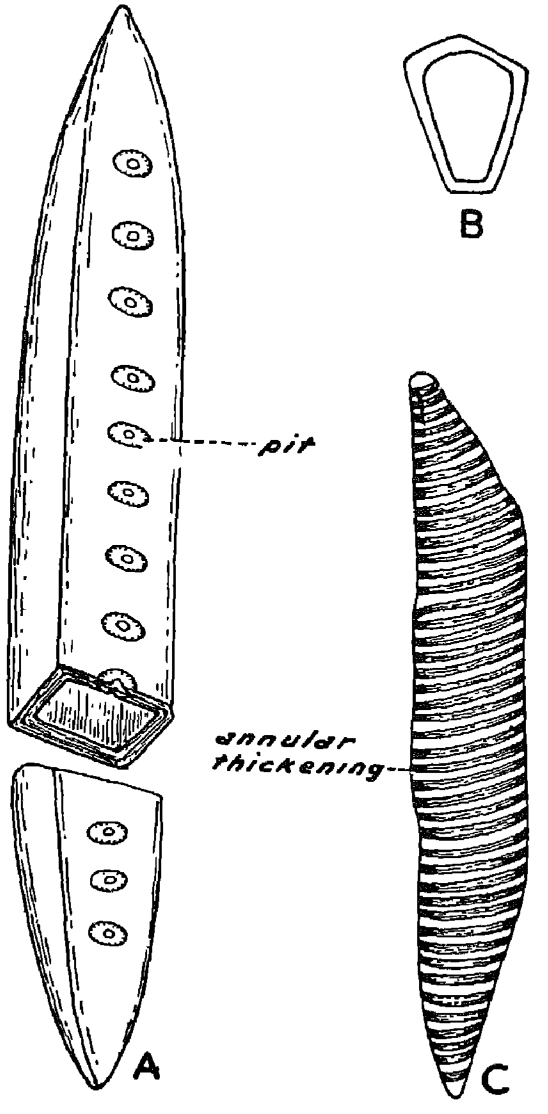

Fig. 6.9. A. Three-dimensional view of a tracheid with pits. B and C. Cross sectional and longitudinal views of a tracheid. From J.B. Hill, L O. Overholts, H W Popp and A.R. Grove, Jr., *Botany, A Textbook for Colleges*, McGraw-Hill Book Company, Inc , New York, 1960

termed a **sieve plate.** Food materials can readily pass through sieve plates. Each sieve tube member has a long parenchymatous cell attached to it. It gives, as it were, company to the tube and is accordingly called a **companion cell.** The companion cells somehow help the sieve tubes in the conduction of food material. In addition to sieve tubes and companion cells, the phloem tissue may also contain fibres and ordinary parenchymatous cells.

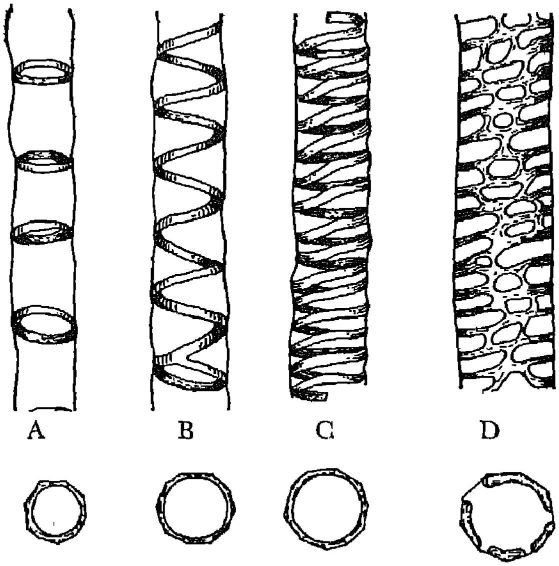

Fig. 6.10. Longitudinal and cross-sectional views of vessel segments with different types of thickenings. A. Annular thickenings. B and C. Spiral thickenings. D. Reticulate thickenings. From J.B. Hill, L.O. Overholts, H.W Popp and A.R Grove, Jr., *Botany, A Textbook for Colleges*, McGraw-Hill Book Company, Inc., New York, 1960.

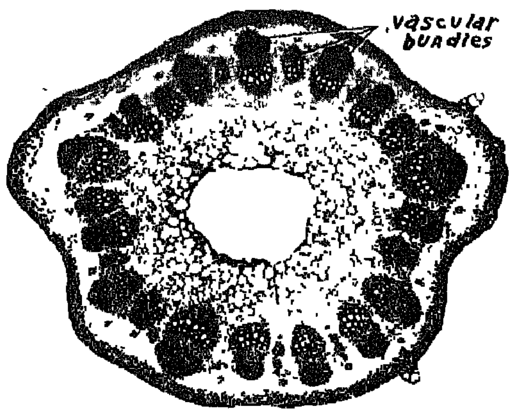

Fig. 6.11 A. The arrangement of vascular bundles in transverse section of a stem. Courtesy of the Department of Botany, University of Delhi.

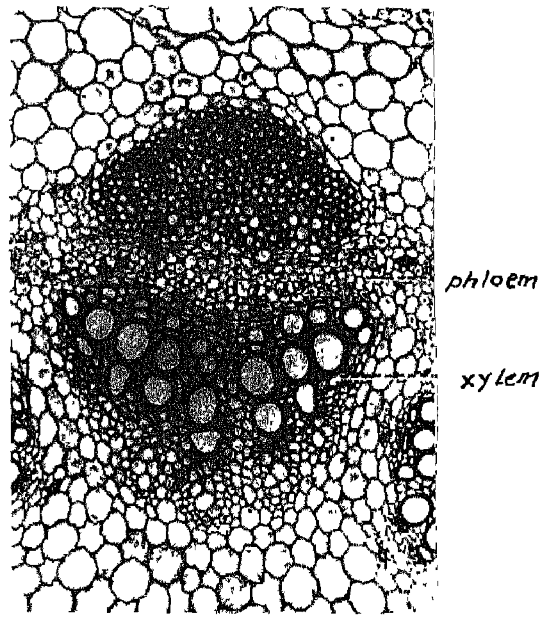

Fig. 6.11 B. One vascular bundle enlarged. Courtesy of the Department of Botany, University of Delhi.

The xylem is popularly known as wood. It consists of two principal types of cells—**tracheids** and **vessels** (Figs. 6.9; 6.10). A tracheid is an elongated cell with tapering ends. It is like a long, empty tube. The wall is highly thickened by deposition of lignin, except at certain circular spots known as **pits.** The arrangement of these tubes is such that the adjacent ones overlap at least near the tapering portions. The pits or unthickened areas are especially common at these places. In effect, therefore, long channels or tubes are formed through which water can move readily.

A xylem vessel is formed by the dissolution of the end walls of a number of cells placed one over the other so that ultimately a single long tubular duct is formed. In some trees the vessels may be a metre or more in length. The mature tracheids

and vessels are dead cells. The thickening of their walls is often in the form of rings, spirals, or a network. In addition to the tracheids and vessels, fibres and parenchyma cells are also found in the xylem tissue.

The two tissues, xylem and phloem, usually occur together, constituting what is known as a **vascular bundle** (Fig. 6.11 B). If you examine the transverse section of a young sunflower stem these bundles can be seen arranged in a ring (Fig. 6.11 A). The veins of a leaf are also the vascular bundles made of both xylem and phloem.

ANIMAL TISSUES

The tissues of animals may be classified into four major groups: (1) **epithelial** or **covering tissue,** (2) **muscular** or **contractile tissue**, (3) **connective** or **supporting tissue**, and (4) **nervous tissue.**

Epithelial Tissue

The epithelial tissue forms the outer protective covering all over the body, and lines the inside of all cavities (Fig. 6.12)

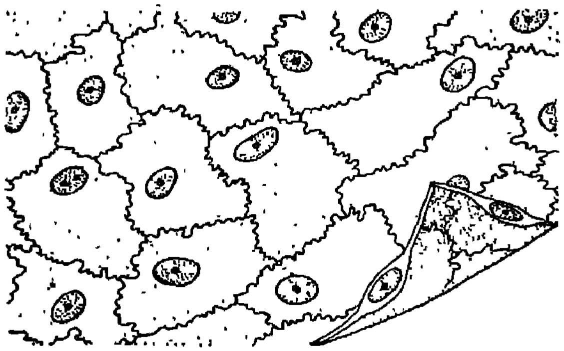

Fig. 6.12. Epithelial layer from the body cavity of frog. Adapted from C W Young, G. L. Stebbins and F G. Brooks, *Introduction to Biological Science*, Harper & Brothers, Publishers, New York, 1956.

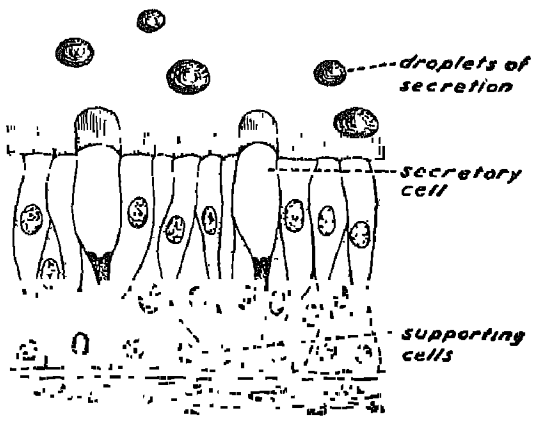

Fig. 6.13. Mucous membrane formed from secretory epithelial cells, and laid over the connective tissue. The cells secrete a slimy mucus. Adapted from C W Young, G L Stebbins and F. G Brooks, *Introduction to Biological Science*, Harper & Brothers, Publishers, New York, 1956

such as those of the stomach, intestines, mouth, throat and wind pipe. Some epithelial cells can secrete drops of mucus, a slimy substance that lubricates the nose and throat. Such a secretory epithelial tissue is known as **mucous membrane** (Fig. 6.13). Cells lining the stomach secrete a digestive fluid. Often the secretory epithelial cells are aggregated into special areas called **glands** (Fig 6.14). As examples may be cited the sweat glands and oil glands of the skin and the salivary glands in the mouth. The epithelial tissue may be simple, i.e., composed of a single layer of cells (Fig. 6.12), or it may be stratified, i.e., made of several layers (Fig. 6.15). The shapes of the cells composing this tissue vary a great deal. The epithelial tissue of the skin, which protects the flesh beneath, has broad, flat cells resembling tiles in a pavement. There are no spaces between these cells, so that the skin can peel off in layers. Frogs often leave big sheets of skin cells in water. The epithelial cells lining

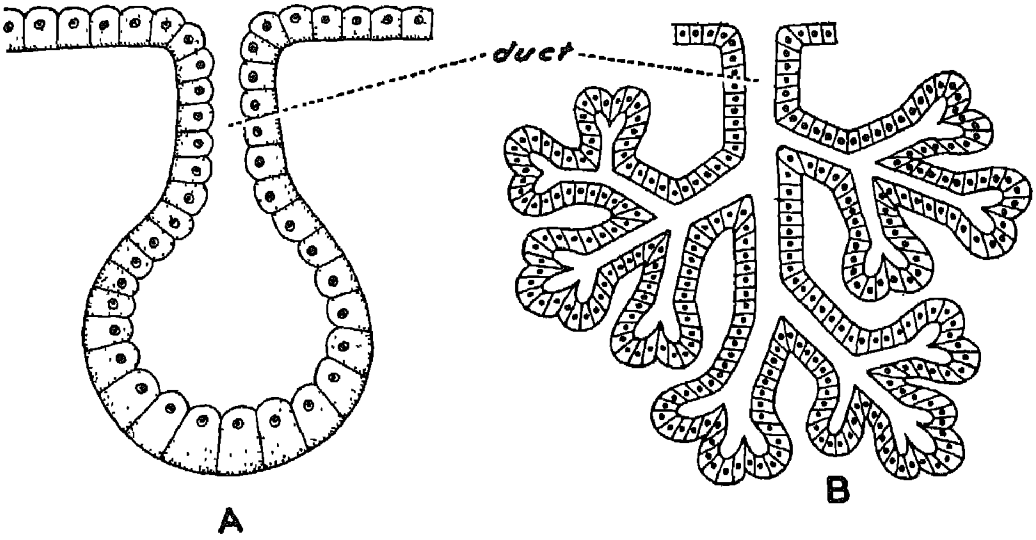

Fig. 6.14. Two types of glands, formed by infolding of the glandular epithelium. A. Sac-like gland from frog's skin. B. Compound gland (salivary gland). From T. I. Storer and R. L. Usinger, *General Zoology*, McGraw-Hill Book Company, Inc., New York, 1957.

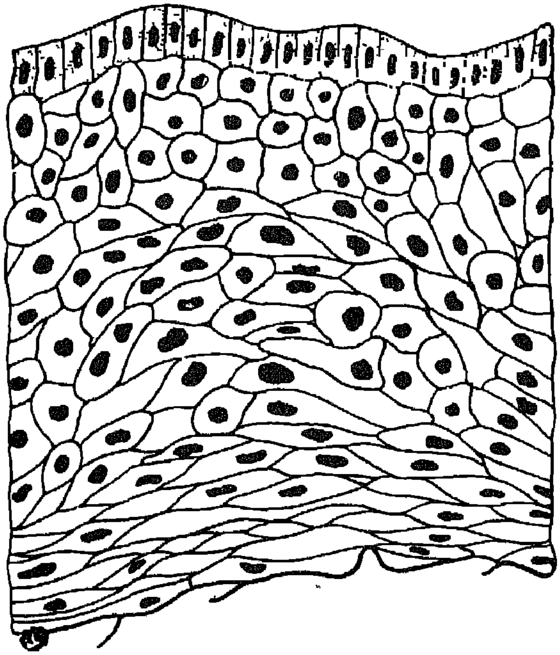

Fig. 6.15. Stratified epithelium. Note the upper cells getting sloughed off. From T J. Parker, W A Haswell and O Lowenstein, *A Textbook of Zoology*, Macmillan & Co Ltd, London, 1957.

the respiratory passages bear numerous hair-like structures called **cilia** (Fig. 6.16) which make lashing movements and tend to sweep germs out of the air passage.

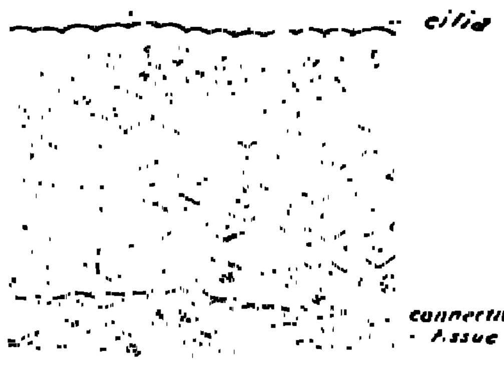

Fig. 6.16. Epithelium from human throat. Cells of the outer layer bear cilia. Adapted from C W. Young, G L Stebbins and F G Brooks, *Introduction to Biological Science*, Harper & Brothers, Publishers, New York, 1956.

Some epithelial cells of the skin may become specialized to receive external stimuli. Such sensory cells are found, for example, in the bodies of earthworms (Fig. 6.17).

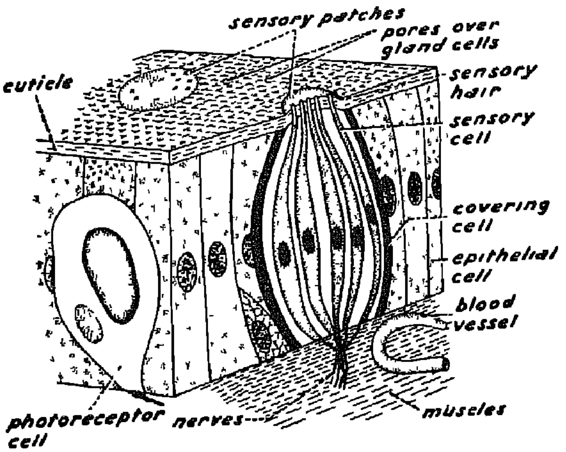

Fig. 6.17. Sensory epithelium of earthworm in three dimensional view. From T I Storer and R L. Usinger, *General Zoology*, McGraw-Hill Book Company, New York, 1957.

Muscular or Contractile Tissue

Did you know that your body has more than 600 muscles which control the various movements? Since all animal life is characterized by movements, this tissue plays an important part in the life of the organism. Tissues composing muscles are of three types: **unstriated, striated** and **cardiac** (Fig. 6.18).

Unstriated (also called smooth, involuntary or visceral) muscles have narrow, spindle-shaped, uninucleate cells. These are called **involuntary muscles** because, their movements are not controlled by the mind. Such muscles are found in many internal organs such as the stomach and intestines where they help to push the food along the alimentary canal. They are also found in smaller blood vessels, breathing passages and the organs concerned with urination and reproduction. These muscles contract and relax very slowly.

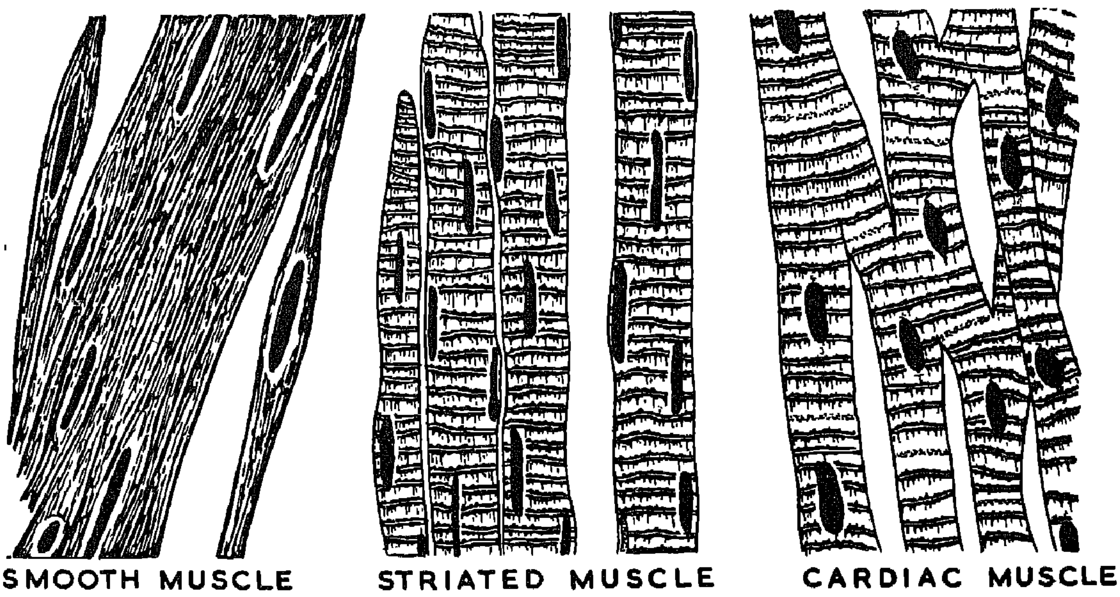

Fig. 6.18. Three kinds of muscle cells. After T J. Moon, J.H. Otto, and A. Towel. *Modern Biology*, Holt, Rinehart and Winston, Inc., New York, 1960.

Striated (also called voluntary, striped or skeletal) muscles are made of long cylindrical

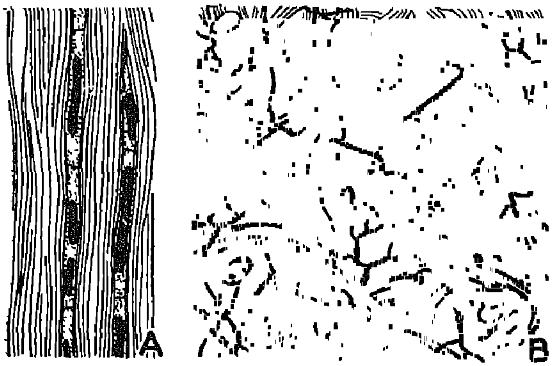

Fig. 6.19. Fibrous connective tissue. A. Fibrous tissue of a tendon. It is made mostly of bundles of white fibres and a few flattened cells between the bundles. B. Elastic tissue made mostly of yellow, branched fibres. It occurs in arteries and vocal cords. After W. T Taylor and R J Webber, *General Biology*, D. Van Nostrand Company, Inc., New Jersey, 1961.

fibres each having many nuclei and enclosed in a thin membrane. Striated muscle fibres form groups or bundles which run parallel to each other. They bear cross bands or striations visible under the microscope. They are just alternating light and dark bands placed at right angles to the long axis. Flesh is made mostly of these muscles. They form nearly 50 per cent of the entire body. They can contract rapidly and are responsible for the quick movements found in animals. Not all the fibres of a muscle contract at the same time and the strength of contraction of the muscle depends upon the number of fibres contracting at a particular time. If a muscle is attached to a bone, the bone will also move whenever the muscle contracts. The contraction of muscles is controlled by nerves that are richly distributed in them. These muscles are called **voluntary** because their action is regulated by mind or will.

Cardiac muscles are found only in the heart. Though striated, they are involuntary, i.e., not under the control of one's will. Your heart beats throughout your life on its own and cannot be controlled by your will. The fibres composing heart muscles are branched and form a close network.

Connective or Supporting Tissue

This tissue, as the name indicates, serves to bind the cells of other tissues and to give them rigidity and support. It is composed of ordinary cells and numerous tiny, rope-like structures called **fibres.** The cells secrete a ground substance or matrix in which they are embedded.

Fibrous connective tissue (Fig. 6 19) contains rows of flattened cells distributed throughout a gelatinous matrix and a mesh of delicate fibres. There are two kinds of fibres the white ones which are non-elastic, unbranched and united into bundles (Fig. 6.19 A), and the yellow elastic fibres which occur singly but are branched extensively to form a network (Fig. 6.19 B). The white fibrous tissue is tough and forms the **tendons, ligaments** and coverings of

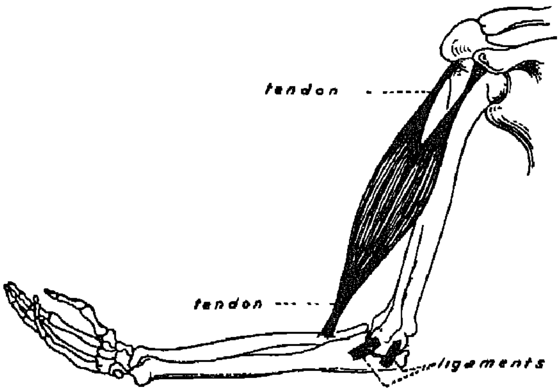

Fig. 6.20. Tendons and ligaments. Adapted from C W Young, G L Stebbins and F. G Brooks, *Introduction to Biological Science*, Harper & Brothers, Publishers, New York, 1956.

muscles Tendons serve to attach muscles to the bones. Ligaments are bands of tissue that hold the bones together (Fig 6.20) The yellow fibrous tissue is found in the walls of the arteries and lungs. It also binds the skin to the muscles underneath it. Fibrous tissue is thus mainly a binding tissue.

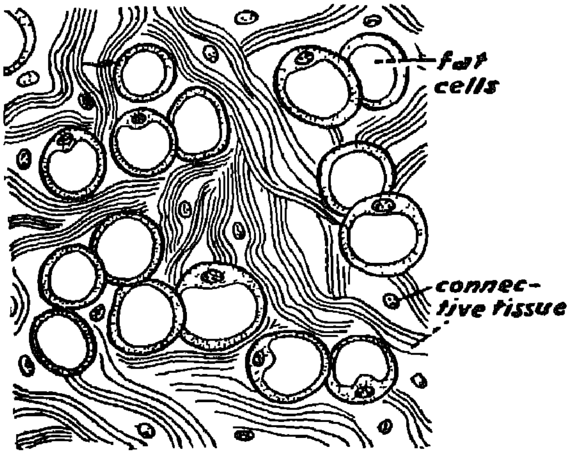

Fig. 6.21. Adipose tissue made of fat-filled cells and fibres. Courtesy of the Department of Zoology, University of Delhi

The **adipose** or **fat tissue** (Fig. 6.21) contains cells filled with fat globules and surrounded by a matrix of yellow and white fibres. It occurs in the deeper parts of the skin, in the bone marrow and around certain organs. It is, therefore, a filling tissue.

Cartilage (Fig. 6 22) is another connective tissue that covers the ends of bones and gives support to certain organs such as the nose, ear, food-pipes and wind-pipes. It consists of a clear ground substance or matrix which contains a large number of spaces, each occupied by one or several cells. The elastic cartilage of the ear contains a large number of fibres in addition to cells.

Bones, the chief supporting structures of vertebrates, are also a type of connective

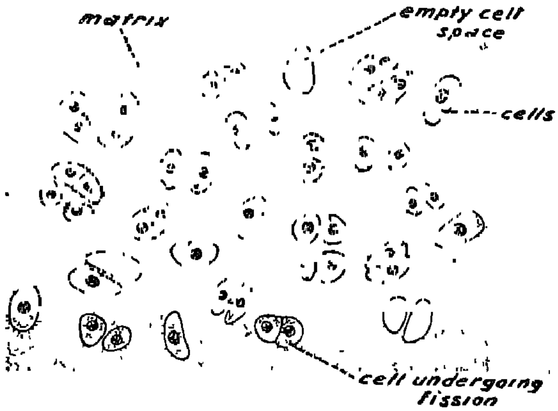

Fig. 6.22. Transverse section of cartilage from the head of frog's femur. From T J Parker, W.N. Parker, B L Bhatia and M A Moghe, *An Elementary Textbook of Zoology for Indian Students,* Macmillan & Co., Ltd , London, 1957

tissue (Fig. 6.23). They have bone cells embedded in a hard matrix of calcium and phosphorus salts. This deposition is in the form of thin concentric layers around a central canal. The bone cells occupy small spaces which are connected to one another by a system of radiating canals.

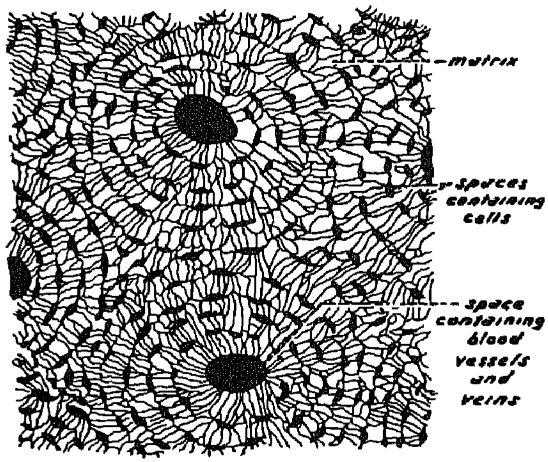

Fig. 6.23. Transverse section of human bone. After W. F. Wheeler and W.E.S. Powers, *Essentials of Biology,* Heinemann, London, 1957.

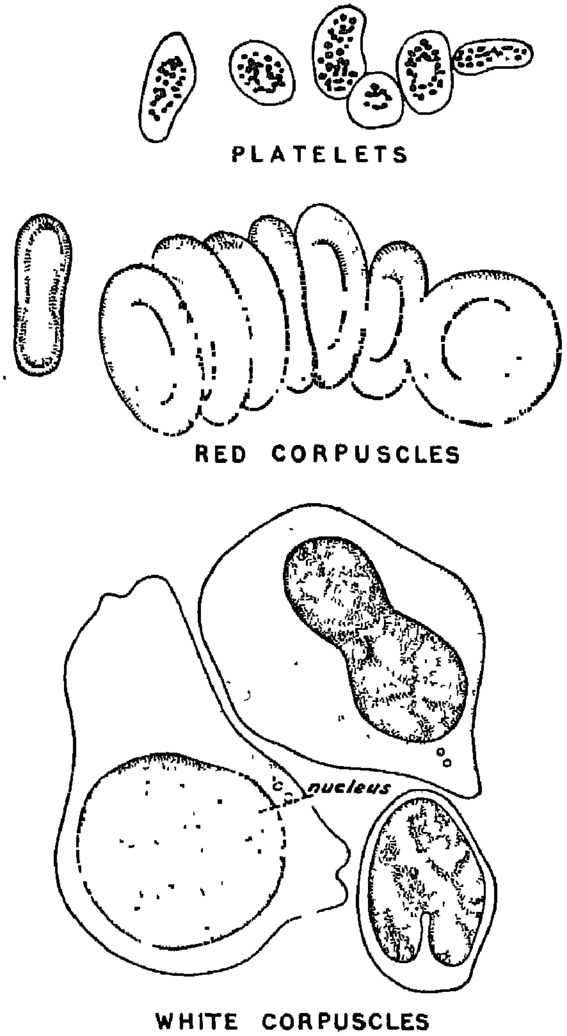

Fig. 6 24, Three types of blood cells. From Elsbeth Kroeber, W. H. Wolff and R L Weaver, *Biology*, D.C. Heath and Company, Boston, 1960

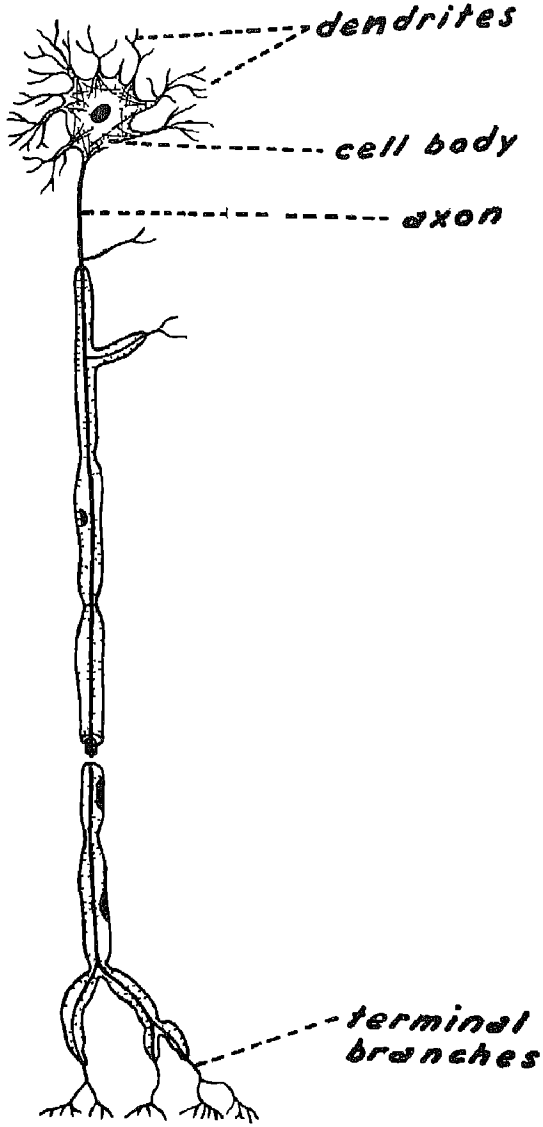

Fig. 6.25. A nerve cell. After G. G Simpson, C. S Pittendrigh and L H. Tiffany, *Life, An Introduction to Biology*, Harcourt Brace and Company, Inc., New York, 1957

The longer bones have a central hollow cavity filled with **bone marrow** which is made of fat cells and red as well as white blood cells. The bones are surrounded by a membrane of connective tissue which carries nerves and blood vessels.

Blood is also a kind of specialized connective tissue which carries food materials and oxygen to all parts of the body. It consists of a fluid medium or **plasma** with numerous red as well as white blood cells

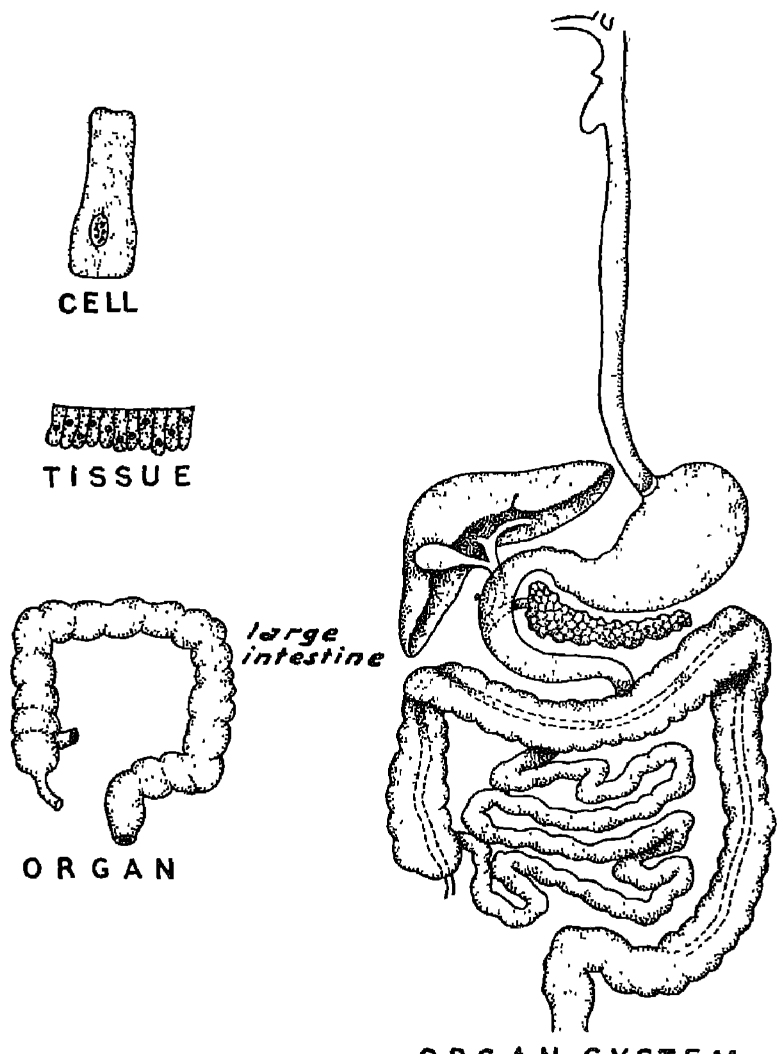

Fig. 6.26. Diagram to show the relation between cells, tissues, organs and organ system. After A.M. Winchester, *Biology And Its Relation to Mankind*, D Van Nostrand Company, Inc , New Jersey, 1957.

Nervous Tissue

This is a very specialized tissue that serves to receive and conduct sensations, and to stimulate other tissues to activity. It is made of nerve cells which convey messages from one cell to the next. A nerve cell or a **neuron** consists of a main body from which numerous, delicate, thread-like fibres are given out (Fig. 6.25). Most nerve cells have fibres of two kinds: the thinner ones or **dendrites** which carry sensations to the cell; and a thicker one or **axon** which carries the messages away from the cell. The nerve cells are located in the brain and spinal cord from where nerve fibres branch out to every part of the body. Some of these fibres may be over a metre in length. The nerves in our bodies are like cables made of many nerve cell fibres bound together by a sheath of connective tissue.

(**corpuscles**) and **platelets** floating in it (Fig. 6 24). The fibres that are so common in other types of connective tissue are only potentially present in the form of a blood protein called **fibrinogen.** When the blood clots, the fibrinogen is precipitated into protein fibres.

Organs and Organ Systems

Two or more kinds of tissues may be associated together to form an **organ** which is a specialized part of the body performing some specific function or functions. There are many organs in our body such as the

kidney, liver, brain, stomach, arm, and so on. Several organs of a body often perform a common function. They constitute an organ system. For instance, the mouth, the stomach, the intestines and several other organs of our body perform a common function of digestion and form the digestive system (Fig. 6.26). In most vertebrates there are other well-marked organ systems for the normal functioning of the body. A group of organ systems working on a co-operative basis constitute an organism. Many organisms living together form a society or colony.

SUMMARY

The multicellular plants and animals are made up of many kinds of cells each doing some special kind of work. When first formed, all cells are more or less alike but gradually they become different from one another to perform various functions. Cells that are alike in structure and function are grouped together and form a tissue.

Two or more types of tissues associated together form an organ. An organ also does a special job or jobs for the benefit of the entire organism.

There are two main types of tissues in plants: meristematic tissues found in the growing regions, and permanent tissues which form the bulk of the plant body. The permanent tissues include the following: parenchyma, collenchyma, sclerenchyma, xylem, and phloem.

Animal tissues are of four main types: epithelial or covering tissue, muscular or contractile tissue, connective or supporting tissue, and nervous tissue.

QUESTIONS

1. How is it advantageous for an organism to be made of different kinds of cells instead of only one kind?
2. What do you understand by cell differentiation?
3. Explain in your own words the relationship between cells, tissues and organs.
4. What kind of muscle is involved in the following processes?
   a. Movement of the arm
   b. Movement of food along the stomach.
   c. Contraction of smaller blood vessels.
   d. Closure of the eye.

5. What change occurs in our tissues when we become fat?

6. What are the main components of xylem? Of phloem?

FURTHER READING

ANONYMOUS 1962. The Way Living Cells are Constructed for the Work They do. *Understanding Science* Vol.1 No.5 pp. 72-74.

FISCHBERG, M. and BLACKLER, A.W. 1961. How Cells Specialize. *Scientific American* Vol.205 No.3 pp.124-140.

LOEWY, A.G. and SIEKEVITZ, P. 1963. *Cell Structure and Function.* Modern Biology Series. Holt, Rinehart and Winston, Inc., New York.

MERCER, E.H. 1961. *Cells and Cell Structure.* Hutchinson Educational Ltd., London.

SWANSON, C.P. 1958. *The Cell.* Foundations of Modern Biology Series. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

CHAPTER 7

The Plants and Animals

IN Chapter 3 we learnt that all living things share certain common characteristics—they are able to move and respire, they take food, they react to stimuli, and they reproduce their own kind. Due to these characteristics they can be easily told apart from non-living things like rocks and, therefore, we call them organisms. There is an infinite variety in form, structure and habits of organisms, yet nearly all of them (we do not yet know whether viruses are plants or animals) can be classified either as plants or as animals. Although most people have a vague idea that both plants and animals are living beings, there seems to be a common belief that the type of life manifesting in plants is somewhat different from that present in the animals. This is incorrect. The life stream flowing in a neem tree and a cow is essentially the same. There are a number of very obvious similarities between plants and animals, in spite of their different external forms.

i. The bodies of both plants and animals are made up of microscopic units called cells.
ii. Both plant and animal cells contain the same unique living substance called protoplasm.
iii. Certain vital processes such as digestion, assimilation and respiration take place in essentially the same manner in plants as well as animals.
iv. The ability to respond to external stimuli, though occurring by different mechanisms, is a common property of both plants and animals.
v. Both plants and animals grow in size by the division and differentiation of cells. Both pass on their hereditary characters to the offspring by the same mechanism.

However, the two groups are so organized that usually they can be recognized from one another without much difficulty. Most plants are fixed to the soil, they are differentiated into stems, leaves and roots, and are usually of a green colour. The green colour is due to the presence of chlorophyll. With its help plants can make their own food from such simple substances as carbon dioxide, water and inorganic salts. Animals, on the other hand, are capable of moving about and of moving their parts, they have such familiar organs as limbs, eyes, head and so on. They have no chlorophyll and, therefore, take in ready-made food. Although these are obvious differences between all higher plants and

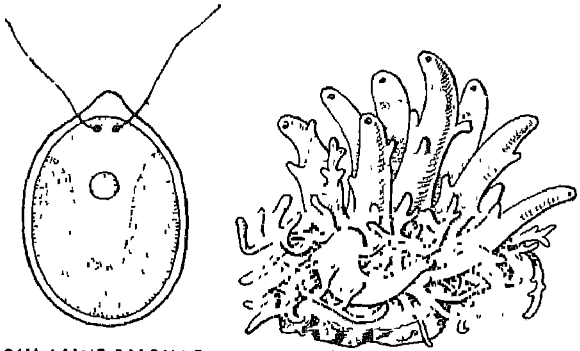

Fig. 7.1. Not all plants are fixed to the soil, nor are all animals motile. Here we see a plant (*Chlamydomonas*) which swims freely in water; and sponges which grow fixed to the substratum. Courtesy of the Department of Botany, University of Delhi.

animals, none of these criteria is absolute. For instance, animals are not always free moving. The sponges and some other lowly animals are fixed to rocks. They do not have organs like mouth, limbs and so on. Similarly, there are unicellular plants like *Chlamydomonas* which can swim as actively as some of the single-celled animals (Fig. 7.1). The touch-me-not plant shows quick movements of its leaves when they are touched. The differences, commonly listed between plants and animals, further break down when lower or simpler forms of life are considered. (If you don't believe this, try recognizing the organisms shown in the lower part of Fig. 7.2 without reading the legend.) One such organism is the one-celled *Euglena*. It has a long whip-like organ called **flagellum** at one end. *Euglena* moves about freely and actively by lashing the flagellum. It ingests particles of food just like some single-celled animals. Like all animal cells it lacks cell wall However, it also contains chloroplasts, which are peculiar to plants and do not occur in animals. With their help it can prepare a part of its own food from carbon dioxide and water in the presence of sunlight. In this respect it resembles plants. *Euglena* (Fig. 7.2 G) and similar other organisms are called flagellates. They share the characteristics of both plants and animals and are believed to be much similar to the organisms which took shape after life began on earth. From these there were probably two lines of evolution in different directions. Those cells which acquired cellulose walls around them started the plant line. The others which lost their chlorophyll were the pioneers of the animal line.

Classification of Plants and Animals

If there were a large library containing thousands of books heaped inthe book-shelves as and when they arrived from the book-sellers, it would be very difficult to find any book when required. It would really be a great confusion and such a library would be of no use. On the other hand, when the library is well-organized, and the books are classified according to the subjects and authors, you may pick out the required book without any difficulty. The situation in the animal and plant worlds is similar. There are more than a million kinds of animals and a little less than a million kinds of plants known to the biologists. It is not possible for any one person to study them all. However, if they are grouped in some convenient way, the study would become much easier because, the characters of a particular group would apply, in a great measure, to all the individuals of that group. Without a suitable method of classification the study of organisms would be in the same state of hopeless confusion as the unclassified books in a library The branch of biology that deals with classification is known as **taxonomy.**

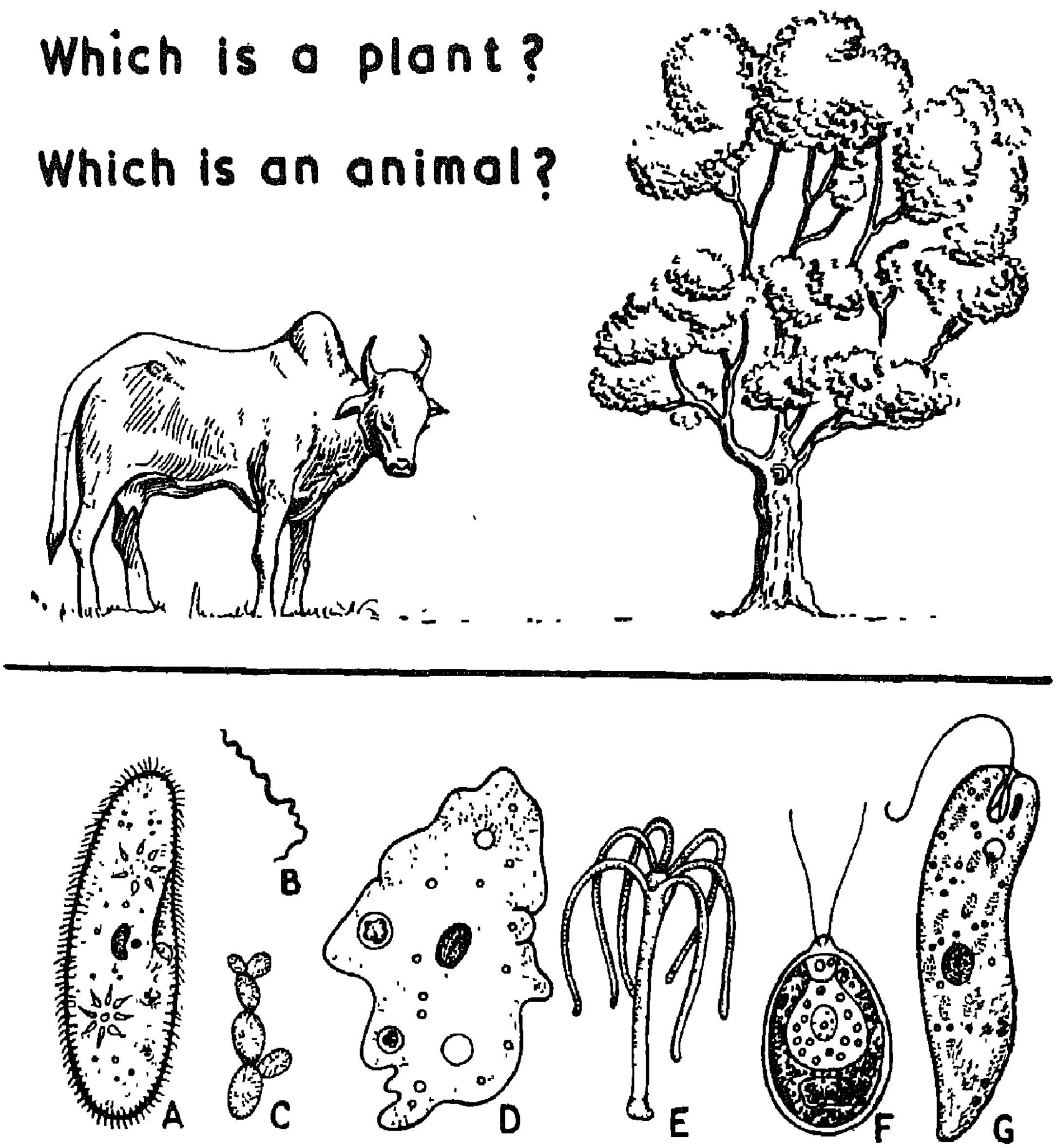

Fig. 7.2. It is easy to tell animals from plants such as a cow and a tree, but with the smaller organisms it is not so easy. A. *Paramecium,* **an animal. B. Bacterium, a plant. C. Yeast, a plant. D.** *Amoeba,* **an animal. E.** *Hydra,* **an animal. F.** *Chlamydomonas,* **a plant. G.** *Euglena,* **plant/animal.** After A.M. Winchester, *Biology And Its Relation to Mankind,* D. Van Nostrand Company, Inc., New Jersey, 1957.

Fig. 7.3. Carl von Linné (1707-1778), a Swedish biologist, is considered the 'Father of Modern Biological Classification'.

Going back to the example of books in the library, it is easy to see that the library would be of little use if the books were classified according to their sizes or colours. Under these conditions it is likely that the books on biology would be distributed in every shelf of the library. In other words this would be a very artificial system of classification and would not serve any useful purpose. The earlier attempts of biologists to classify plants and animals were of a similar nature. They separated plants into such groups as herbs, shrubs and trees; and animals into categories like water animals, land animals and air animals. This obviously was of little use. Then in the 18th century there came a Swedish biologist named Carl von Linné. He is popularly known as Linnaeus. He developed a new scheme of classification and a uniform method of naming plants and animals based on their natural relationships. Subsequently other scientists made many improvements over his method. As a result of this, plants and animals are now classified into certain well-marked categories which not only make their study easier but also indicate the relationships between various kinds of organisms.

All individuals having many important characters in common, and different from all others in one or more ways, are placed in a category called **species.** Thus the common cat, monkey, orange, and apple all represent one species each. All the individuals of a species are believed to have been derived from common ancestors and can breed with one another to produce fertile offspring which resemble them When biologists speak of kinds of organisms they actually mean the species. If a number of different species are found to possess certain basic characters in common, they are placed in a higher category called the **genus.** A genus may, therefore, be defined as a collection of closely related species. For example, there are a number of animals like lion and tiger which resemble a cat in certain respects in spite of their obvious differences. Accordingly, the cat, the lion, and the tiger represent three different species but all belong to the same genus (Fig 7.4). Similarly there are certain fruits which resemble the orange in many essential respects and are popularly known as citrus fruits. We have the common loose-skinned orange, the sweet lime, and the lemon. They are different from one another in certain features and can easily be told apart. The orange, the lime, and the lemon represent different species belonging to the same genus (Fig 7.5).

Similarly, like genera are grouped into **families,** families into **orders** and orders

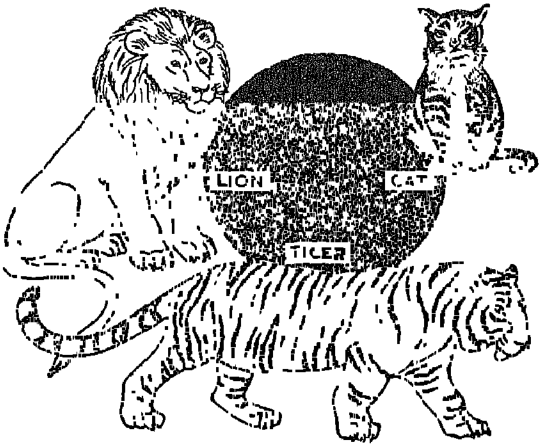

Fig. 7.4. The lion, the tiger and the cat make three species of a single genus (*Felis*).

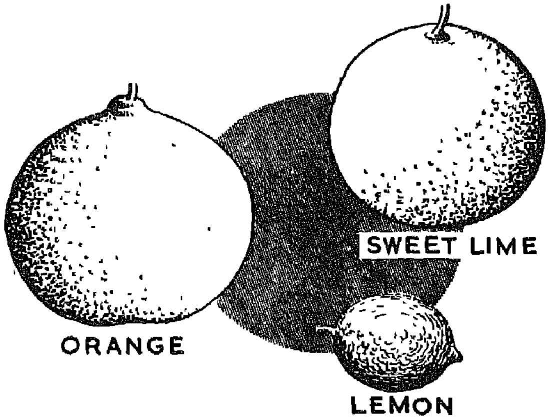

Fig. 7.5. The orange, the sweet lime and the lemon are three species of a single genus (*Citrus*) Courtesy of the Department of Botany, University of Delhi.

into **classes.** The classes are in turn grouped into bigger categories called divisions or **phyla** (Gk. *phylon*=race or tribe). The phyla are put under the highest category such as the **plant** or **animal kingdom.** It may be noted that higher the category, the less will be the resemblances or common characters between the organisms belonging to that category. For instance, the cat, the lion and the tiger which resemble each other in so many respects, are grouped into a class which includes such different animals as the cow, the rat, the dog and even man. The common character which holds these animals together within the class is the presence of a vertebral column, hairs, and mammary glands. The organisms belonging to a phylum have still fewer characters in common. For instance, the infinite variety of flowering plants, and the conifers like the pines and cedars all come under one phylum of plants. The common character which keeps them in this phylum is the production of seed. The Table on page 63 shows where some common plants and animals, including man, belong.

The Plants and Animals Have Names

Has it ever occurred to you how difficult it would be to carry on a conversation if we did not have names for different things? A word like snake at once recalls to our minds a particular animal; the word rose immediately makes us visualize the shape of a beautiful flower. The practice of naming is one of the greatest inventions of man. Just as it is difficult to talk about things without having their names, it is difficult to talk of any branch of biology without using names for the organisms. Thus we have names like cat, rabbit, dog, elephant, rose, pea, and gold mohur. However, these names are as variable as the people who use them. Thus the name for dog will be different in different languages like Hindi, Marathi, Gujarati, Bengali, Tamil, and Telugu. Not only that, the name of a particular organism in the same language also varies a great deal. Thus, the common names of a weed like *Argemone* (Fig. 7.6) in Hindi are as variable as

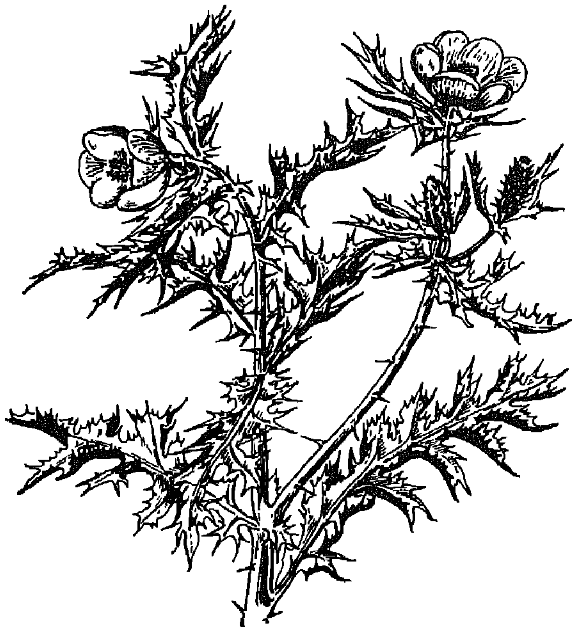

Fig. 7.6. *Argemone mexicana*, **a common weed in our country, is known by this scientific name throughout the world but its vernacular names vary from place to place even in the same state.** Courtesy of the Department of Botany, University of Delhi.

'Firangi Dhatura', 'Pila Dhatura', 'Sial Kanta', 'Katela', 'Ujar Kanta', 'Bharband', 'Kandhari', 'Satyanasi Buti', etc. These names are known only to a few people and are therefore of very restricted use. They are comparable to the nicknames of the people, which are used only by some of their acquaintances. Moreover, common names are often misleading and the same name may be applied to entirely different organisms in different parts of the world. For instance, the name 'corn' may mean wheat, maize or any miscellaneous cereal crop. If scientists wish to refer to a particular organism, they resort to scientific names which are widely recognized throughout the world and are given in accordance with a plan laid down by Linnaeus. A scientific name consists of two parts: the first part is the **generic name,** and the second is the **specific name.** Thus the scientific name of cat is *Felis domestica*, that of tiger is *Felis tigris*, and that of orange is *Citrus reticulata*. This system of giving two names to an organism is called the **binomial system.** Such names also give an idea that the different species are related to each other. Thus, the names of cat, tiger and lion (*Felis domestica, Felis tigris* and *Felis leo* respectively) clearly show that these three species are related to each other. The peculiar thing about these names is that the specific name of the individual comes second while the group or generic name comes first, like the names in a telephone directory, where Anil Sharma is written as Sharma Anil. When you read through the pages of this book, you will

Table 7.1. The classification of five different organisms

	Orange	Rice	Dog	Cat	Man
Kingdom	Plant	Plant	Animal	Animal	Animal
Phylum	Spermatophyta	Spermatophyta	Chordata	Chordata	Chordata
Class	Angiospermae	Angiospermae	Mammalia	Mammalia	Mammalia
Order	Rutales	Glumiflorae	Carnivora	Carnivora	Primates
Family	Rutaceae	Gramineae	Canidae	Felidae	Hominidae
Genus	*Citrus*	*Oryza*	*Canis*	*Felis*	*Homo*
Species	*reticulata*	*sativa*	*familiaris*	*domestica*	*sapiens*

come across many scientific names printed in italics. It is not necessary for you to always quote scientific names in your everyday conversation but when you wish to write the results of your experiments on a certain organism, to some other biologists in a different part of the world, you have to be definite about the organism so that the biologist does not understand you wrongly. The scientific name of the organism is to be preferred in such cases. You might ask why these names sound so unfamiliar and difficult to pronounce. This is because at the time when first scientific names were given Latin was the most popular and scholarly language. Accordingly, Linnaeus used Latin for coining them. The special advantage of using this language is that unlike others it does not change from time to time. It is a dead language.

SUMMARY

With a few exceptions all living things are either plants or animals. They have certain common characteristics like the presence of cellular structure and an ability to grow and reproduce. Higher plants and animals are easily distinguished from one another. However, the lower forms are not easy to distinguish. Perhaps the most constant feature of plants is that their cells have well-defined walls made of cellulose. On the other hand, the cells of animals have only plasma membranes.

There are no less than two million kinds of organisms on the earth. For the convenience of proper study and for indicating relationships between the organisms, biologists have grouped them into different categories on the basis of similarities and differences. Organisms are grouped together first into a kingdom and then into phyla, orders, classes, families, genera and species.

Like all other things plants and animals also have names. Biologists use scientific names because these are definite and constant throughout the world.

QUESTIONS

1. Supposing you came upon a tiny piece of material of biological origin. How would you decide whether it was derived from a plant or an animal ?
2. Which of the following items is characteristic of plants or of animals, or of both?
   a. Small cells.
   b. Cytoplasm.
   c. Cellulose walls.
   d. Sexual reproduction.
   e. Vacuoles.
3. What is the advantage of having a system of classification of organisms?
4. What is the basis of modern classification?
5. What is the advantage of using scientific names instead of common or popular names?
6. What do you understand by the term species?
7. Why has *Euglena* been classified as a plant as well as an animal?

FURTHER READING

ANONYMOUS 1962. The Classification of Plants. *Understanding Science* Vol.1 No.9 pp.136-138.

COMSTOCK, A.B. 1960. *Handbook of Nature-study.* Comstock Publishing Co., Inc., New York.

HARDIN, G. 1961. *Biology: Its Principles and Implications.* W.H. Freeman and Co., London.

JACQUES, H.E. 1946. *Living Things and How to Know Them*. William C Brown and Co , Iowa.

SHUTTLESWORTH, D E. 1952. *Exploring Nature with Your Child.* Greystone Press, New York.

SINGER, C. 1931. *Story of Living Things.* Harper and Brothers, New York.

CHAPTER 8

The Major Plant Groups

WHEN we speak or think of plants we usually associate them with flowers, but there are thousands of plants which do not produce any flowers. Some of them are so small indeed that you cannot see them with the unaided eye. A knowledge of their structure and reproduction was acquired only after the invention of the microscope in the 17th century. Broadly, plants are divided into four major divisions or phyla : Thallophyta, Bryophyta, Pteridophyta and Spermatophyta. We shall now have a brief excursion through all these groups of plants.

POND SCUMS, MOULDS AND BACTERIA (PHYLUM THALLOPHYTA)

You will be surprised to learn that there is a vast assemblage of plants whose bodies are not differentiated into roots, stems and leaves. Botanists call them thallophytes (Gk. *thallos*=a young branch that has no root, stem and leaves; *phyton*= plant). Their bodies are called **thalli** (singular — thallus). Thallophytes are believed to be among the first plants which originated on the earth. By gradual elaboration and modification, in a span of millions of years, some of these plants have given rise to the diverse variety of plants that we see today.

Biologists separate these primitive plants into four groups—Algae, Fungi, Lichens and Bacteria.

Algae

You must have noticed that the water in a pond is sometimes covered with a green or bluish green scum. You probably thought that the water was contaminated. May be you were right; but if you were to examine a little of this scum under a microscope, you would be wonderstruck at the indescribable beauty of some of the forms contained in it. Most of these beautiful forms are algae. They are found both in freshwater as well as in the sea, on damp soil, in the waters of hot springs (85°C), and even in snow.

Algae may be unicellular or multicellular (Fig. 8.1). If unicellular, they may be motile (i.e., capable of free movement) or non-motile. Many unicellular forms live together in small colonies or irregular masses. The multicellular ones may form filaments, plates of tissue, or rarely they may have bodies with stem-like and leaf-like structures as seen in some seaweeds.

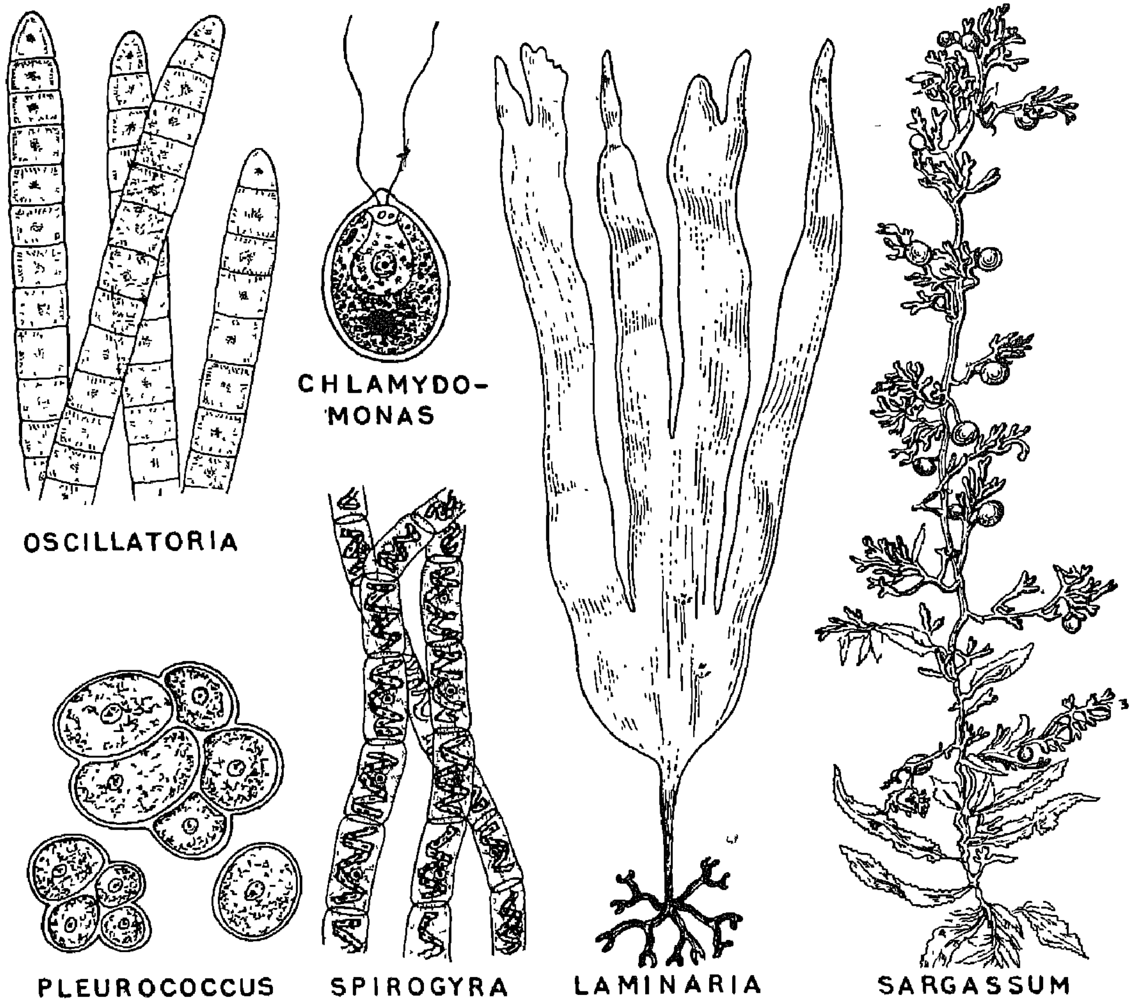

Fig. 8.1. Algae—the simplest of green plants. Courtesy of the Department of Botany, University of Delhi.

Since the body of an alga does not possess a woody stem, it cannot grow to a great height. However, certain seaweeds attain a length of nearly a hundred metres. Their bodies are supported by the sea water so that they can hold themselves erect in spite of the absence of woody tissues in them.

All algae contain chlorophyll in their cells, and hence they can manufacture their own food from simple substances just like a pea plant. In many types the green colour is hidden by other pigments. Thus, there may be blue-green, brown, red or sometimes even purple algae.

Fungi

In the rainy season we often find a whitish, hairy or cobweb-like growth on a piece of stale bread left carelessly in a corner. You might also have observed a greenish powdery growth on a wet pair of shoes stored in a shoe rack, and during your morning walks you might have sometimes sighted white or pink umbrella-like structures growing on waste lands. All these forms are called fungi (singular—fungus) They do not have chlorophyll and hence they cannot manufacture their food themselves. They live either as **parasites** on other living organisms or as **saprophytes** on decaying organic matter Among the commonest of the fungi are the yeasts. An yeast plant is a single, rounded cell, too small to be seen without a microscope Like bacteria, the yeast cells float

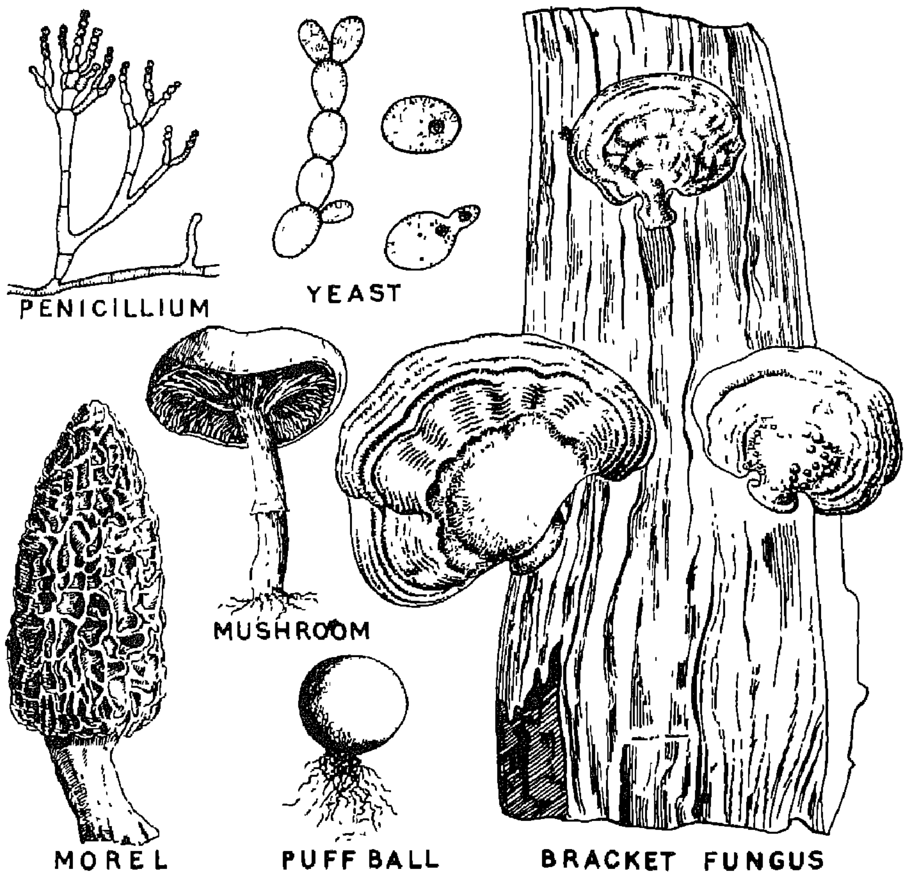

Fig. 8.2. The Fungi—plants without chlorophyll. Note that except in yeast, where the plants are unicellular, only the reproductive bodies have been shown here. The mycelia occur within soil or other substrata. Courtesy of the Department of Botany, University of Delhi.

about in the air and if they happen to fall in a sweet liquid medium, they multiply very rapidly and bring about its fermentation. These are the plants that are used for making wines and baking bread. The plant body of most other fungi or moulds, as they are popularly called, is usually in the form of a number of branching threads forming what is known as a **mycelium** (plural—mycelia). The individual threads are known as **hyphae** (singular—hypha). Fungal hyphae may be so closely intertwined as to form large masses of a definite form such as the mushrooms, puffballs, morels, bracket fungi and the like (Fig. 8 2). If you happen to break a puffball, a fine 'dust' comes out of it. This 'dust' is actually made up of millions of spores of the fungus. If the spores fall on a suitable medium they start new plants.

Lichens

The lichens (Fig. 8.3) form a group of strange plants which occur as greyish-green growths on barren rocks, on the bark of trees or on the ground. They are peculiar because they are composite organisms each consisting of an alga and a fungus living together in such an intimate association that the two appear as a single organism. The algal cells are enmeshed between the fungal hyphae. As a result of this close relationship, both the organisms benefit from each other. The fungus absorbs a part of the food material manufactured by the green alga, and provides the alga in return with water and minerals. Such a relationship of mutual benefit is called **symbiosis.**

Bacteria

Bacteria are microscopic, single-celled organisms, often known as 'germs' or 'microbes'. They occur everywhere—in the air, in the food we take, in soil and in water. Our bodies carry millions of them. Bacteria were first observed by the Dutch lensmaker Antony van Leeuwenhoek in 1675, but they came into prominence as a result of the work of Louis Pasteur and Robert Koch who showed that certain kinds of bacteria are the cause of many diseases in man and animals. They are the smallest organisms known; being about 0 5 to 3

Fig. 8.3. The lichens are composite organisms made up of an alga and a fungus and grow on barks and twigs. The lichen here is *Usnea florida* abundantly found in Mussoorie. Cousrtesy of the Department of Botany, University of Delhi.

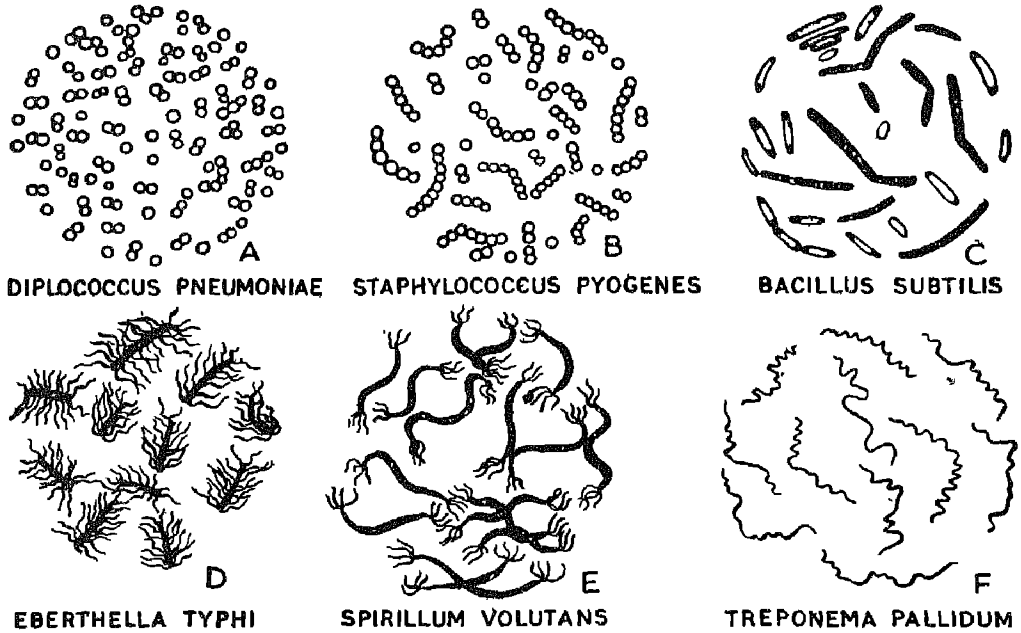

Fig. 8.4. Shapes of bacterial cells. A and B. Spherical forms. C and D. Rod-like forms. E and F. Spiral forms. From E.N. Transeau, H C. Sampson, and L.H. Tiffany, *Textbook of Botany*, Harper & Brothers, Publishers, London, 1940.

microns in length or diameter. Bacterial cells have mainly three shapes—spheres, rods or spirals (Fig. 8.4). Some cells bear little hair-like processes called cilia. By the beating of the cilia they can move about in water. As a rule, they do not contain chlorophyll and are therefore unable to prepare food from simple substances.

The organization of a bacterial cell is simple. There is no nucleus, but the nuclear material or chromatin occurs in the form of one or more lumps. The cytoplasm lacks vacuoles. There is a cell membrane surrounded by a distinct cell wall. For this reason bacteria are classified under plants, not animals. Being the cause of many deadly diseases, and being also of immense use to mankind, bacteria are ardently studied by medical doctors and bacteriologists.

THE MOSSES AND THE LIVERWORTS (PHYLUM BRYOPHYTA)

After some showers of rain, old fences, walls, gutters, trunks of trees, and even the ground are often covered with a bright green carpet. From a distance this appears like the algal scum in a pond but on a closer observation you will find that it consists of small green plants made of tiny stems and leaves. These are the mosses (Fig. 8.5). You can easily strip them from the ground because they have no roots, but only thin, branched threads called **rhizoids** (Gk. *rhiza*=root; *eidos*=form) which anchor them to the ground. Some of the plants may show long slender stalks growing from them. Each stalk ends in a swollen spore

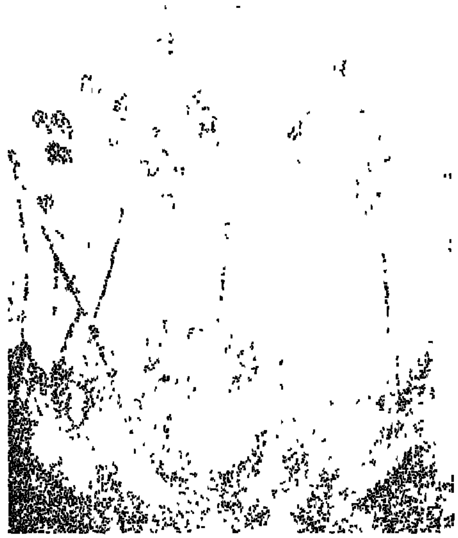

Fig. 8.5. A patch of mosses. Note the long, slender stalks bearing the capsules or spore sacs. Courtesy of R N. Chopra, Department of Botany, University of Delhi.

Fig. 8.6. A patch of the liverwort *Fimbriaria* **from a moist shady slope at Pachmarhi.** Courtesy of M M Johri, Department of Botany, University of Delhi.

case or capsule which is full of spores. These are eventually discharged and begin the growth of new plants.

Related to the mosses are some other tiny plants called liverworts. Most of these are also similar to the moss plants in having slender stem and tiny leaves but some are entirely different in that they have no stems and leaves. These grow in spreading patches of green, forked, ribbon-like structures (Fig. 8 6) lying flat on moist ground. They are specially conspicuous on hill stations, where moist shady slopes are covered with them. Rhizoids are given off from their undersurface which attach them rather loosely to the soil The name liverwort refers to the resemblance of some of them to the lobes of a liver. Though bryophytes are small and simple plants and some of them have thallus-like bodies, they are in several respects more highly organized than the algae and fungi, as will be clear from a detailed study of some members in Section II.

Most of the bryophytes have no direct use for man. However, when these tiny plants die, they enrich the soil by adding organic matter and make it suitable for the growth of larger plants.

FERNS AND THEIR RELATIVES (PHYLUM PTERIDOPHYTA)

In contrast to the plants you have studied in the last two groups, the pteridophytes (Gk. *pteris*=fern, *phyton*=plant) have well-formed stems, roots and leaves with woody tissues. They are, therefore, more highly organized than the bryophytes. Water can be easily carried to different parts of the plant through its conducting tissues. The most familiar of the pteridophytes are the ferns which are grown in every garden for their elegant green leaves. Many ferns grow wild in our forests and hill stations.

The stems grow horizontally below the ground while above it are seen a number of

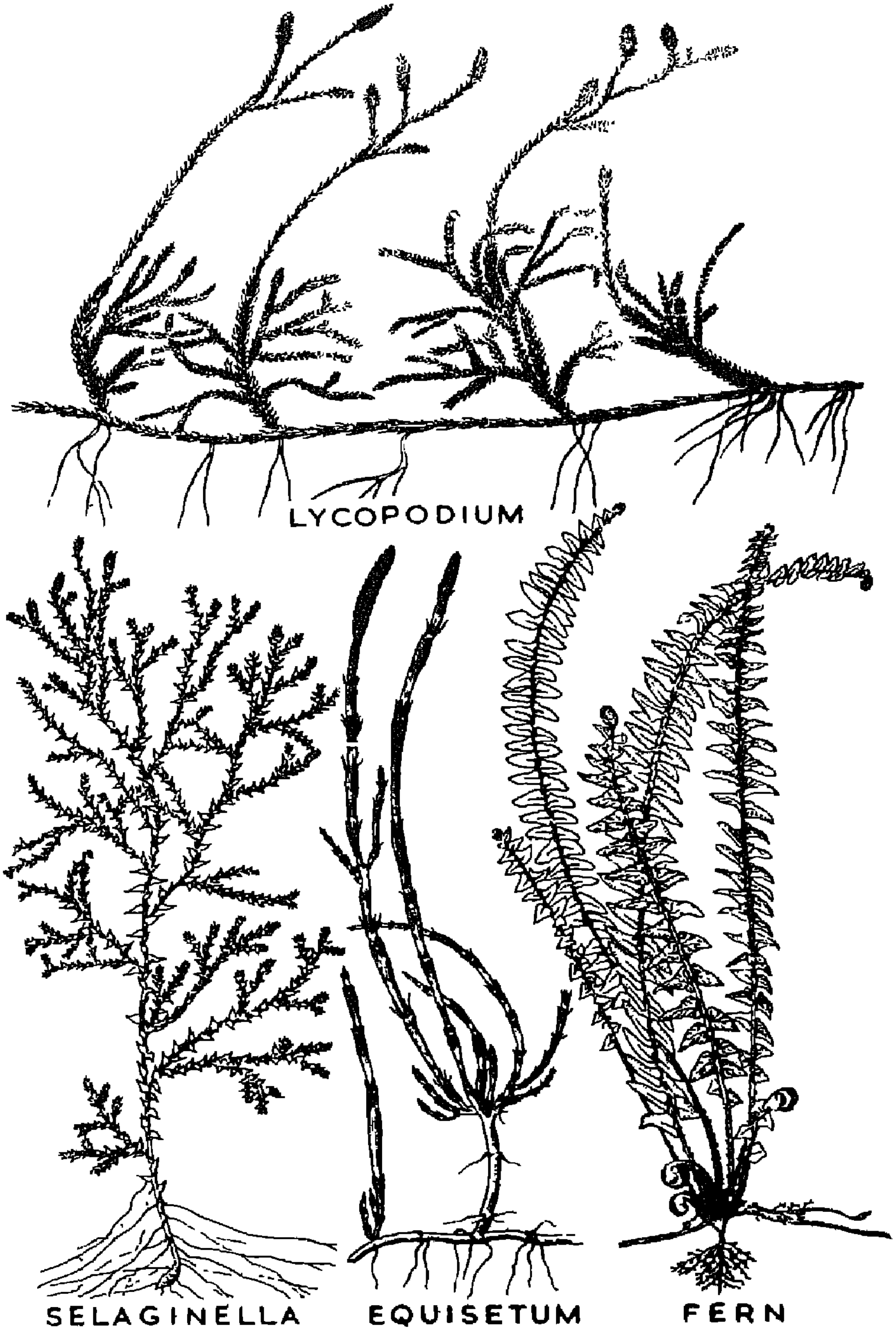

Fig. 8.7. Some members of the Pteridophyta. Courtesy of the Department of Botany, University of Delhi

feathery, green leaves. The youngest leaves are coiled like a watch-spring and unroll as they grow older. Some ferns have tall columnar stems bearing a crown of leaves and thus look like trees. Ferns do not produce flowers and seeds. Instead, they produce spores in brown spore cases or sporangia borne generally on the underside of the leaves

Related to ferns are certain other pteridophytes (Fig 8 7) called the club mosses (*Lycopo ium* and *Selaginella*) and the horsetails (*Equisetum*). Pteridophytes were very abundant millions of years ago and the huge deposits of coal of the world are derived partly from their remnants.

THE SEED BEARING PLANTS (PHYLUM SPERMATOPHYTA)

The most highly organized plants are the spermatophytes (Gk *sperma*=seed, *phyton*= plant) or seed plants As the name indicates they all produce seeds. In this group are included practically all the familiar plants you see around you. The grain crops, the vegetables, the flowering plants in your garden, the

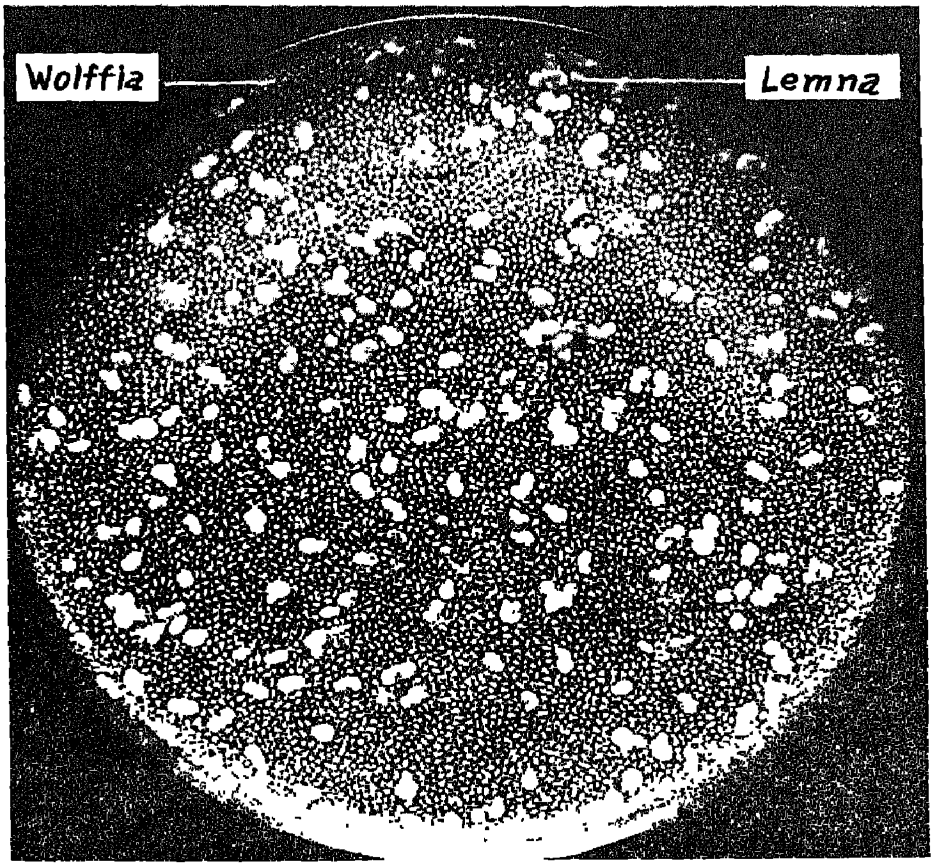

Fig. 8.8. The duckweeds. ***Wolffia*** **is the smallest of the flowering plants.**
Courtesy of S.C Maheshwari, Department of Botany, University of Delhi

fruit trees, the tall trees in the forest—all belong to this group. Its members may be very tall, or they may be as small as a pin-head. Duckweeds (*Wolffia* and *Lemna*) belong to the latter category. They grow as a scum in ponds (Fig. 8.8). As an example of the other extreme may be mentioned the red-woods some of which are over 100 metres tall (Fig. 8.10). Seed plants grow mostly on land, but may also occur in swamps, on the surface of water, or even submerged.

Like ferns, seed plants have true roots, stems, and leaves; but in addition they also bear seeds. You will recall that a spore is usually a single cell, but a seed is a complex multicellular body with a tiny young plant inside it.

There are two types of seed plants. In one, the seeds are not enclosed within any covering but stand freely exposed. Such seeds are called uncovered, and plants that bear such seeds are known as **gymnosperms** (Gk. *gymnos*=uncovered, *sperma*=seed). The pines, the cedars (Fig. 8.11), the sago-palm and the thujas are examples of this group. They often bear their seeds in elegant, woody cones. In the second main group of seed plants, however, the seeds are enclosed in a case or covering which forms the familiar fruit. Plants with such enclosed seeds are known as **angiosperms** (Gk. *anggeion*=a case or vessel; *sperma*=seed) or plants with enclosed seeds. They are also called flowering plants since all of them produce flowers of some sort.

The angiosperms in turn are divided into two groups. If you break open a soaked bean seed into halves, you will find two large, fleshy **cotyledons** between which is sandwiched the young plant in a rudimentary condition (Fig. 8.9 A).

Plants whose seeds have two cotyledons are known as **dicotyledons.** The date seed, on the other hand, has only one cotyledon. Grasses too, have one cotyledon (Fig.8.9B). Such plants are known as **monocotyledons.** You can also tell a monocotyledonous plant (monocot, for short) from a dicotyledonous one (dicot, for short) by looking at their leaves. The veins on the leaves of monocots run parallel to one another (parallel venation). In the leaves of dicots the veins form a network (reticulate venation). Other differences between monocots and dicots will be enumerated later.

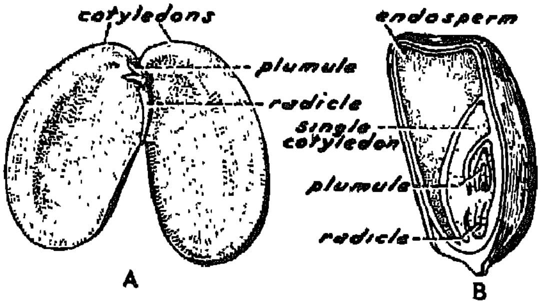

Fig. 8.9. A. Parts of a bean seed. The seeds of dicotyledons have two seed-leaves or cotyledons which may serve to store food for the growth of the embryo. B. Longitudinal section of a maize 'seed'. The seeds of the monocotyledons have always one cotyledon. Courtesy of the Department of Botany, University of Delhi

LOWER AND HIGHER PLANTS

In Section 2 and elsewhere in the book you may often come across the expressions 'lower plants' and 'higher plants'. These terms refer to the fact that some plants, such as the thallophytes and bryophytes have a less elaborate organization than the others, namely pteridophytes and spermatophytes. The less elaborate ones are at a lower stage

Fig. 8.10. The giant redwoods (*Sequoia sempervirens*) **of California (USA) are among the tallest trees.** Courtesy of the Chicago Natural History Museum.

Fig. 8.11. A stand of *Cedrus deodara* photographed at Chakrata. Courtesy of R.N. Konar, Department of Botany, University of Delhi.

of evolution. They are said to be primitive, i.e., they are more like plants that lived in the past. The plants with a more elaborate organization are at a higher stage of evolution, i.e., they are 'modern'. The relationships between different phyla of plants are shown in Fig. 8.12.

THE IMPORTANCE OF PLANTS

Has it ever occurred to you that the presence of plants makes possible the very existence of all animals including man? The food we eat, the clothing, and the oxygen that we breathe—all come from plants. The basic food for all organisms is prepared by green plants which alone possess the unique green pigment, chlorophyll. In the presence of sunlight the plants produce sugars from carbon dioxide and water. These sugars are later changed into starches, oils, proteins and a host of other substances like dyes, drugs, fibres, perfumes and so on. In this process of food manufacture, oxygen is set free into the air. This oxygen, which we take in as we breathe, is essential to life. Since animals do not have chlorophyll, they cannot make food and oxygen; only the plants can do so.

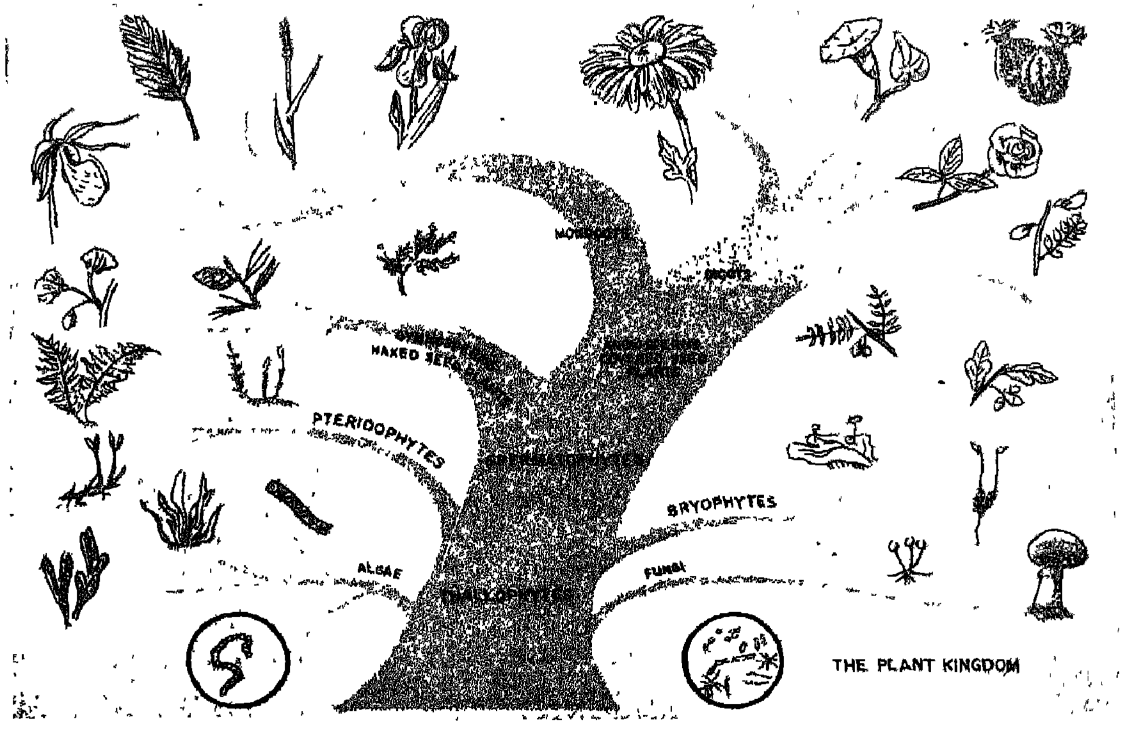

Fig. 8.12. This plant 'tree' shows the relationships among plants. The plants shown are representatives of different groups. From C Gramet and J Mandel, *Biology Serving You*, Prentice-Hall, Inc, Englewood Cliffs, New Jersey, 1959.

Fig. 8.13. Collection of latex by tapping a rubber tree. Courtesy of the Rubber Board, Ceylon.

You will perhaps now realize the truth of the biblical saying: 'all flesh is grass'. Some animals derive their food directly from plants as by eating wheat, rice, corn, beans, vegetables and fruits. Others depend upon plants indirectly. They may eat animals which live on grass, or fish which eat algae.

Shelter in the form of wood for building houses is also provided by plants. Wood is also useful as fuel. Even the coal, diesel oil or petrol which we burn as fuel are derived, at least partly, from plants which lived millions of years ago.

Our clothing too comes chiefly from plants—cotton and flax being the most important. Even the raw material (cellulose) for the so-called synthetic fibres like rayon is obtained from plants. Hemp, jute and sisal yield fibres used for making ropes and gunny bags.

Besides providing these basic necessities, plants are also the sources of an infinite number of other materials (Fig 8.14). To mention only a few, paper is made from bamboos and the wood of gymnosperms or even from cotton. Rubber is made chiefly from the milky juice of the rubber tree (Fig. 8.13). The beverages like coffee, tea, cola and wine, and sugar which sweetens our dishes, are all plant products. Important drugs like quinine, penicillin and belladona are again the gifts of plants. To this long list we are sure, you can add many more items. In fact if you ever think of your activities during a day, there will be hardly any activity which does not involve plants directly or indirectly.

Some plants, although not directly beneficial, nevertheless render silent service. Water running down a slope often carries away the soil particles, making the soil useless for cultivation. The roots of plants form a meshwork and prevent erosion.

The non-green plants, bacteria and fungi, are no less important. They are the active agents of decay and decomposition. You might have so far considered decay and decomposition as harmful processes but actually they are very important. The supply of molecules of each element to living things is limited. By decay the basic materials of life are kept in circulation and made available for building new living substances. If decay were prevented, materials once incorporated into our bodies would be locked up permanently.

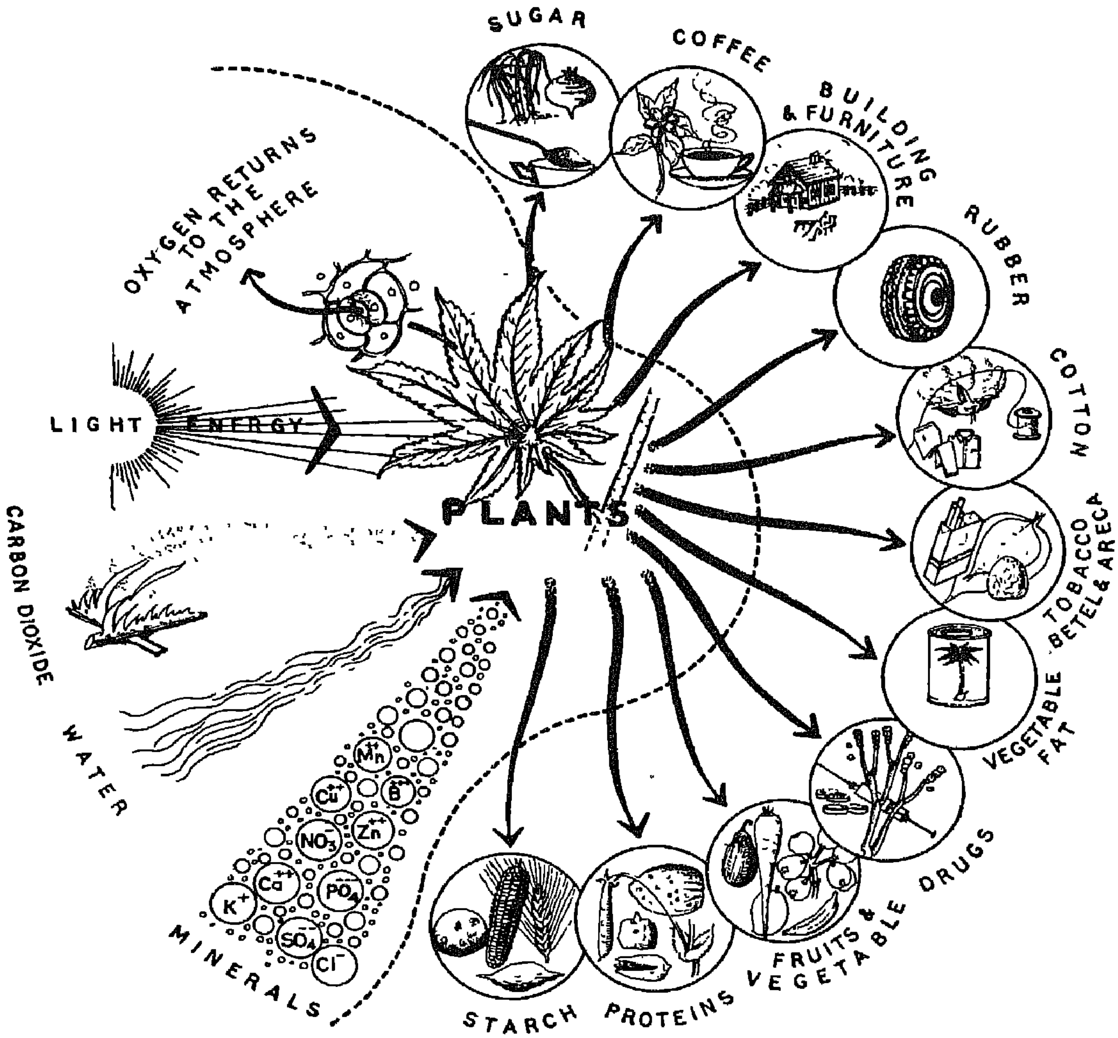

Fig. 8.14. From carbon dioxide and water, and in the presence of sunlight, green plants manufacture a wide variety of substances which are used by man for food, clothing, shelter and drugs. Oxygen, so essential for all life, is also made available by green plants. Courtesy of the Department of Botany, University of Delhi.

Some plants make human and animal life uncomfortable. Bacteria cause such deadly diseases as typhoid, tuberculosis, diphtheria and plague. Many fungi also cause diseases in men and animals. Of these ringworm is the most common. Some fungi attack important crop plants and reduce their yield considerably.

To these material benefits and losses from plants you might add the aesthetic appeal and relaxation derived from them. The fragrance of a rose, the flash of colours in the garden and the curious shapes of many flowers will enchant even the most fastidious of men and women.

SUMMARY

The plant kingdom is broadly divided into four major divisions or phyla: Thallophyta, Bryophyta, Pteridophyta and Spermatophyta. The Thallophyta contains plants which have no root, stem or leaf. Their bodies are called thalli and they are believed to be among the first plants which originated on the earth. Thallophytes have been separated into four groups—Algae, Fungi, Lichens and Bacteria The division Bryophyta contains Mosses and Liverworts. Plants of this group may be either thalloid or have stem-like and leaf-like organs. They are attached to the ground by means of rhizoids. The Pteridophyta consists of ferns, club mosses and horsetails. They have well-developed stems, roots and leaves with vascular tissues, but do not produce flowers and seeds. The most highly organized plants are the spermatophytes or seed plants They are divided into two groups: (a) gymnosperms, which bear naked seeds, and (b) angiosperms, whose seeds are enclosed in ovaries. The angiosperms are divided into the monocotyledons, whose embryo has only one cotyledon; and the dicotyledons, whose embryo has two cotyledons. Since the thallophytes and bryophytes have a simple organization and do not possess any vascular tissue they are called lower plants. They are supposed to be primitive. The pteridophytes and spermatophytes have an elaborate organization with vascular tissues, so they are called higher plants and are considered to be more modern. Plants are of immense importance—they provide us oxygen, food, drugs, fibres, wood, and many other things. Animals would not survive on earth if plants were to disappear.

QUESTIONS

1. What would happen if all the plants were to disappear from the earth?

2. What plants or plant products did you use during the last week?

3. You are given an assortment of plants on your laboratory table. What character will you look for in order to label a particular specimen as: (a) angiosperm, (b) moss, (c) alga, and (d) fungus?

4. Which of the following groups of plants contain chlorophyll?

   a. Bacteria

   b. Algae

   c. Fungi

   d. Gymnosperms

   e. Angiosperms

   f. Ferns and mosses

FURTHER READING

ANONYMOUS 1962. The Classification of Plants. *Understanding Science* Vol.1 No.9 pp.136-138.

BOLD, H.C. 1958. *The Plant Kingdom* Foundations of Modern Biology Series. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

HUTCHINSON, J. and MELVILLE, R. 1948 *The Story of Plants and Their Uses to Man.* P.R. Gawthorn, Ltd., London.

NORMAN, A.G. 1962. The uniqueness of plants. *American Scientist* Vol 50 pp. 436-449.

CHAPTER 9

The Major Animal Groups

DO you know that a bat is not a bird, a whale is not a fish and a spider is not an insect ? To a common man all animals are just an assemblage of living things. However, when one classifies them according to their resemblances and differences, they come to have a different meaning. Biologists have identified, named and described more than a million different kinds of animals. In this chapter you will have a 'bird's eye view' of the various groups of animals so that when you look at a particular animal you will know its position in relation to the others and it will have more meaning to you than ever before.

Broadly speaking, there are two main groups of animals. The first group is that of the **invertebrates.** It includes those animals which have no bones in their body. Some of them do have a protective shell but this lies outside the body. To this group belong such animals as the 'shankhs' and cowries, insects, spiders, and corals. Some invertebrates are made of a single cell while others have many-celled bodies.

The second group is that of the **vertebrates** which includes all animals having a backbone or vertebral column together with other supporting bones inside their body. To this group belong all the familiar animals such as the fish, rats, rabbits, squirrels, snakes, whales, monkeys, cattle, elephants and man.

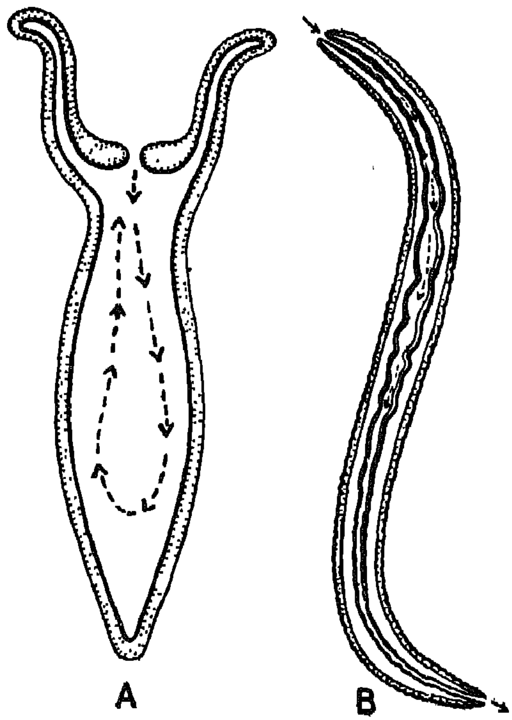

Fig. 9.1. Two types of body-plan in Metazoa. A. Body built on the plan of a single hollow sac. B. Body built on 'tube within a tube' plan. Courtesy of the Department of Botany, University of Delhi.

From the point of view of organization, animals can also be divided into two groups: the **Protozoa** or the one-celled animals, and the **Metazoa** or the many-celled animals. The bodies of the metazoa range from a few cells to large bulky structures like those of whales. The body-plan is of two distinct types. In the primitive types there is a single sac-like cavity with just one opening which serves both as mouth and anus. In the more advanced types, however, the body is built on a 'tube within a tube plan' (Fig. 9.1). This means that there is a separate digestive tract or alimentary canal which has two openings, the mouth and the anus, and a second cavity called the body cavity or **coelome.** It is a closed cavity which contains within it the alimentary canal and some other organs of the body.

ANIMALS WITHOUT BACKBONES—INVERTEBRATES

This group contains a much larger number of animals than the next group of vertebrates. However, since many of them are too small to be seen without a microscope and still others often live underground, they usually remain unnoticed.

One-celled Animals (Phylum Protozoa)

If you were to examine a drop of pond water through a microscope, you would be astonished to see a variety of little 'animalcules' made of just a single cell and actively swimming about in water. All these

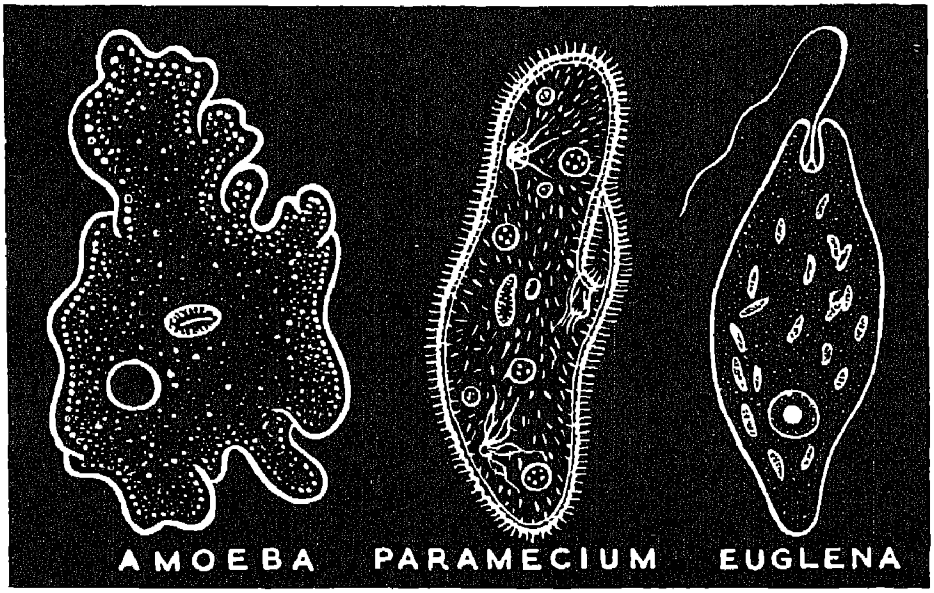

Fig. 9.2. One-celled animals — the Protozoa.

single-celled animals (Fig. 9 2) are placed in one phylum—the **Protozoa** which means the first animals (Gk. *prōtos*=first; *zoon*= animal). This name has been given to them because biologists believe that animals of this type were the first to take shape when life began on earth. Although they have been in existence for millions of years, their presence was noticed only 300 years ago when Antony van Leeuwenhoek peeped through his crude microscopes.

Protozoans are found everywhere—in soil, in water, and even within the bodies of other animals including man. Malaria, amoebic dysentery and sleeping sickness are caused by protozoans that live as parasites in our bodies. Another familiar protozoan that you might see in pond water is *Amoeba*, a tiny blob of jelly that changes its shape every moment. A third type is a slipper- or cigar-shaped animal *Paramecium* which is comparatively larger in size and bears little hairy structures, the cilia, all over its body. There are also certain forms which are 'biological puzzles' since they are neither true animals nor true plants. For example, *Euglena* is a single elongated cell having a long whip-like hair or flagellum (Fig. 9.2). By lashing this it drives itself about actively. At one end of the cell there is an opening that serves as a mouth for the ingestion of food. Near this is a red spot that is sensitive to light. The strange feature is that this little cell is full of chloroplasts, and can prepare a part of its food from water and carbon dioxide. There are many other similar forms possessing one or more flagella and are often spoken of as flagellates.

Porous Animals—The Sponges (Phylum Porifera)

The animals of this phylum are commonly known as sponges (Fig. 9.3). They live mostly in the sea but one form occurs in fresh water. They grow fixed to some object and have neither a stomach nor other organs that we usually associate with animals The body is merely a thick-walled bag that has many holes (pores) all over. To these they owe the name **Porifera** (L. *poros*=pore; *ferre*=to bear). Water pushes in through these pores and flows out through the opening at the top which is misnamed as 'mouth' although this actually serves as anus.

The common market sponge is only the framework or skeleton of the sponge animal which was at one time full of living cells, covering and lining each pore. The live sponge is a slimy mass composed of two layers of cells. Sponges are the simplest multicellular animals and differ from the protozoans in that they consist of many cells which are not very different from one another but which live together as one body.

The Hollow Sac Animals (Phylum Coelenterata)

Coelenterates (Gk. *koilos*=hollow; *enteron* =intestine or gut) are animals of a simple construction living mostly in the sea. The body is little more than a bag with only one opening. The food is taken in and the undigested stuff passed out through the same opening. The hollow space inside is a kind of 'stomach' since food is digested in it. All coelenterates have little finger-like processes called **tentacles** around the 'mouth'. The body wall that surrounds the 'stomach' consists of two layers of cells. *Hydra*, which is the simplest of the coelenterates (Fig. 9 4) is found attached to leaves in ponds. If you observe carefully, you can recognize the hydras as whitish threads about 0.5 cm long with frayed ends.

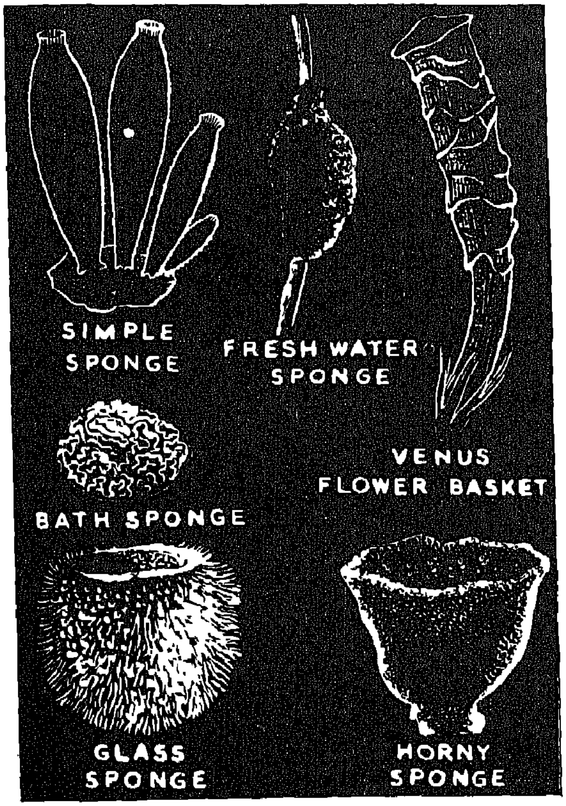

Fig. 9.3. Porous animals — the sponges.

All other coelenterates live in the sea. A common example is the jellyfish (Fig. 9.4) which looks something like an inverted glass cup with a fringe (curtain) hanging from within. Some coelenterates such as the sea anemones are pinkish or blue-green and look like beautiful flowers when they open out their tentacles. When in danger, they pull in their tentacles and appear as little mounds.

There are still other forms in this phylum that build the coral islands. Corals (Fig. 9 4) are actually the calcareous (made of calcium compounds) skeletons secreted by anemone-like animals. With the passage of time these depositions become quite enormous.

The Flatworms–Animals That Can Glide (Phylum Platyhelminthes)

The platyhelminths (Gk. *platys*=flat; *helmin*=worms) are interesting animals with thin flat bodies (Fig. 9.5). Most of them

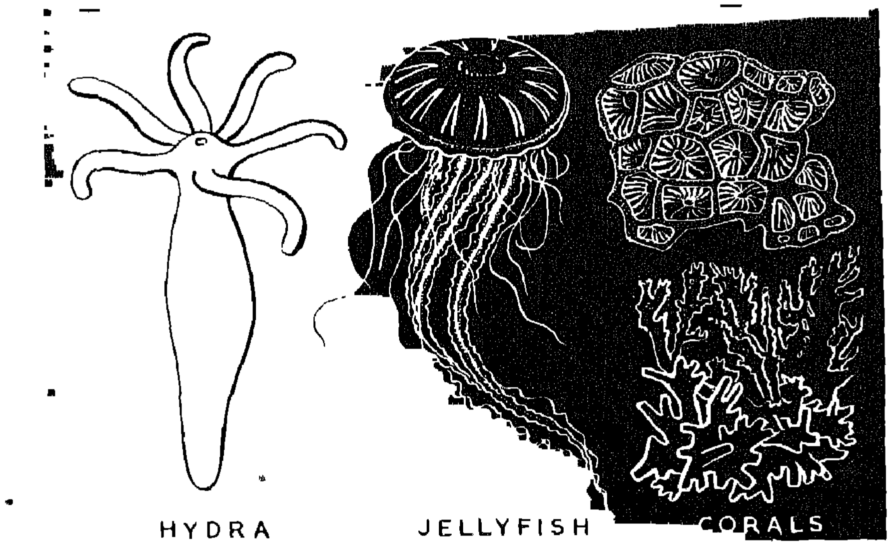

Fig. 9.4. The hollow sac animals.

live as parasites in the bodies of other animals but a few like *Planaria* occur in pond water. This animal has become famous because of the many experiments performed on it by biologists. The strange thing about it is that if its body is cut into two or more pieces, each piece grows (regenerates) the missing part. Examples of parasitic flatworms are the tapeworm and the liver fluke. The tapeworm infests the human intestine and may sometimes reach a length of over six metres. It looks like a long, jointed ribbon with a small head. It is peculiar in that it has no digestive system of its own. It simply absorbs the digested food that surrounds it in the human intestine.

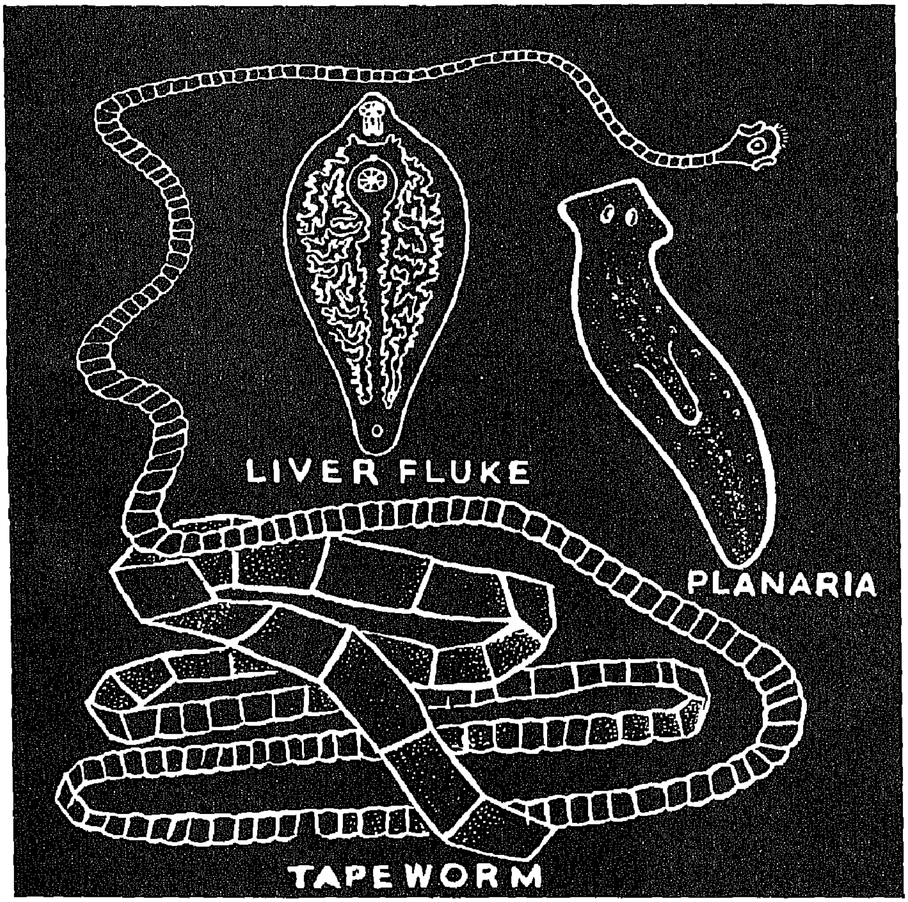

Fig. 9.5. The flatworms.

The Roundworms (Phylum Nematoda)

On displacing a stone in a wet, shady place you may have encountered occasional slender, thread-like worms actively coiling and uncoiling on the surface of the soil. These and their many relatives are grouped in the phylum **Nematoda** or **Nemathelminthes** (Gk. *nema*=thread; *helmin*=worms). Some roundworms live in the soil and in water but a good many inhabit the bodies of plants, animals and man and live as parasites (Fig. 9.6). Notorious examples of these are the hookworms and the so-called stomachworms. They cause severe anaemia (lack of red blood) in people infested with them. They reduce the vigour and enthusiasm of their hosts. Unlike the flatworms, the roundworms possess both a mouth and a hind anal opening.

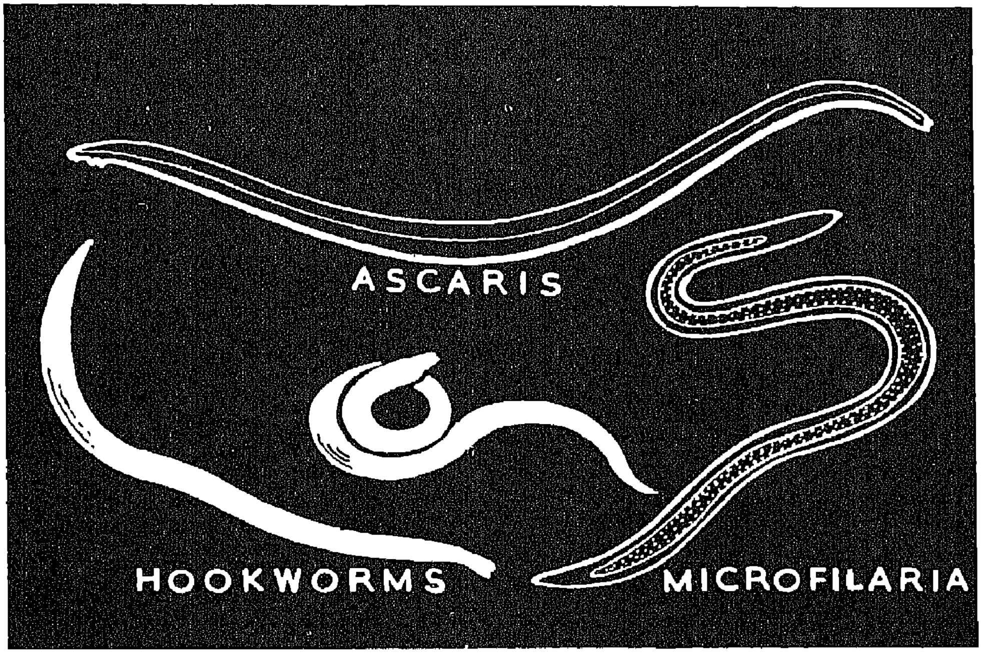

Fig. 9.6. The roundworms. Microfilaria is the larva of the worm filaria which causes elephantiasis.

The Soft-bodied Animals (Phylum Mollusca)

Most of you are perhaps familiar with the cowries, 'shankhs' and numerous other sea-shells of fascinating designs and colours.

You may have taken them to be pieces of stones collected from the seabed and cut into cute shapes. Actually, all of these once contained soft-bodied animals (Fig. 9.7) that are grouped under the phylum **Mollusca** (L. *molluscus*=soft). You might have heard of 'devilfish' or octopus that attacks the divers in the sea. This is also a mollusc that has no outer shell, but has long tentacles studded with powerful suckers. Its large, cold, wicked-looking eyes give it a terrifying appearance The smaller types are harmless but the larger ones can be quite dangerous even to man. They often shoot a jet of ink into water to dodge the enemies. Other mulluscs include slugs and snails which live on moist soil, and mussels which inhabit fresh water.

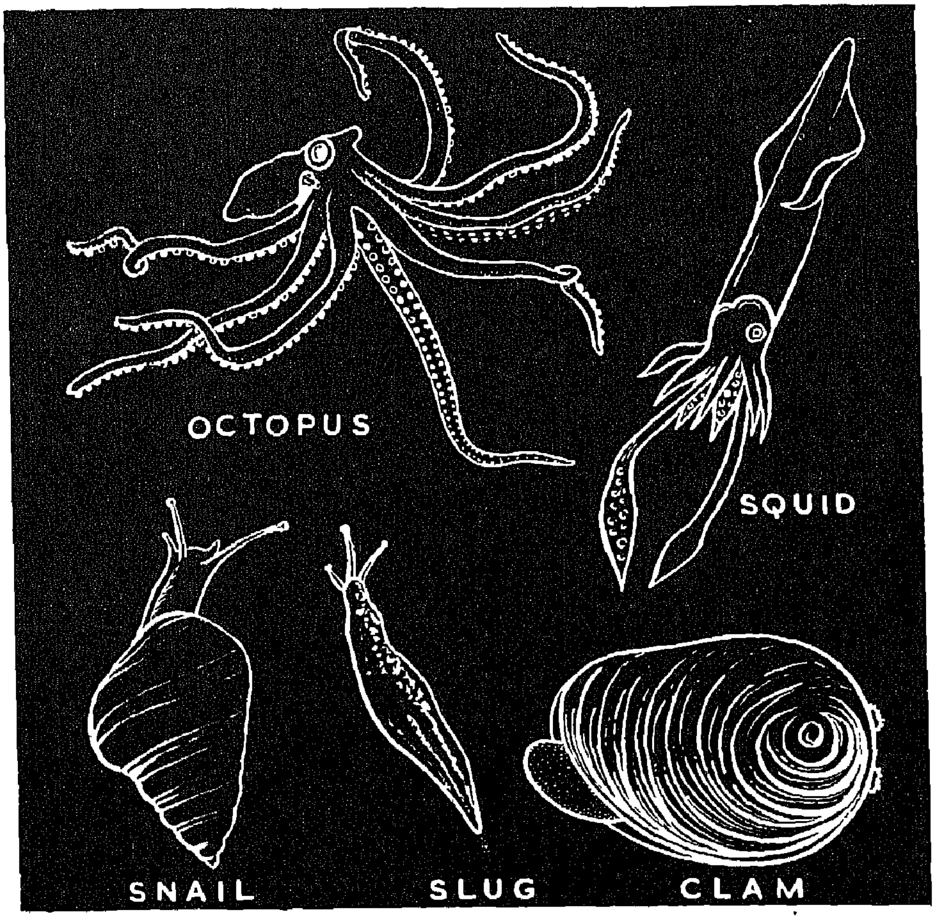

Fig. 9.7. The soft-bodied animals.

The Segmented Worms (Phylum Annelida)

The familiar earthworms that crawl on the lawns at night, especially after the rains, and the leeches that some quack village 'doctors' use to rid the patients of bad blood are examples of yet another type of worms (Fig. 9.8). Their body is composed of rings or segments—hence the name of the phylum **Annelida** (L. *annulus*=a ring, *eidos*= form). They are made on the plan of a tube within a tube There is a long body cavity within which is located another tube or the digestive tract with an opening at either end. The body cavity is enclosed by the body wall and is filled with a fluid. This plan of body structure is also seen in all the higher phyla of animals. The segmented worms are found in fresh water, damp soil and sea. Some like the leeches are parasitic The earthworms swallow earth and decaying leaves. The part of the soil that cannot be digested is passed out as little ropes called castings. When the earthworms eat their way through the soil, they mix it quite thoroughly. The famous biologist, Charles Darwin, calculated that there may be as many as 50,000 worms in an acre of land and may turn over more than 18 tons of soil in a year! In this way they keep the soil fertile.

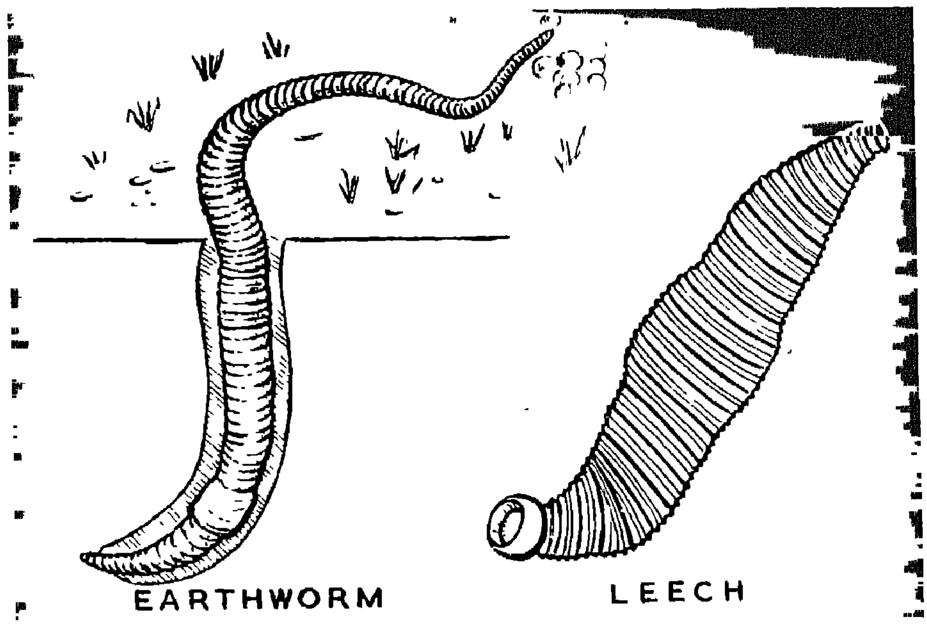

Fig. 9.8. The segmented worms.

Animals With Jointed Legs (Phylum Arthropoda)

This is the largest group of animals including nearly three-fourths of the entire animal world. There is hardly a place on earth that does not have some members of this phylum. The members of this great group are called animals with jointed legs because they have six or more legs with several joints in each. The biological name of the phylum is **Arthropoda** (Gk. *arthron* =joint; *podos*=foot). Ants, flies, bees, cockroaches, butterflies, beetles, spiders, scorpions, lobsters, crabs and centipedes are some of the examples (Fig. 9.9).

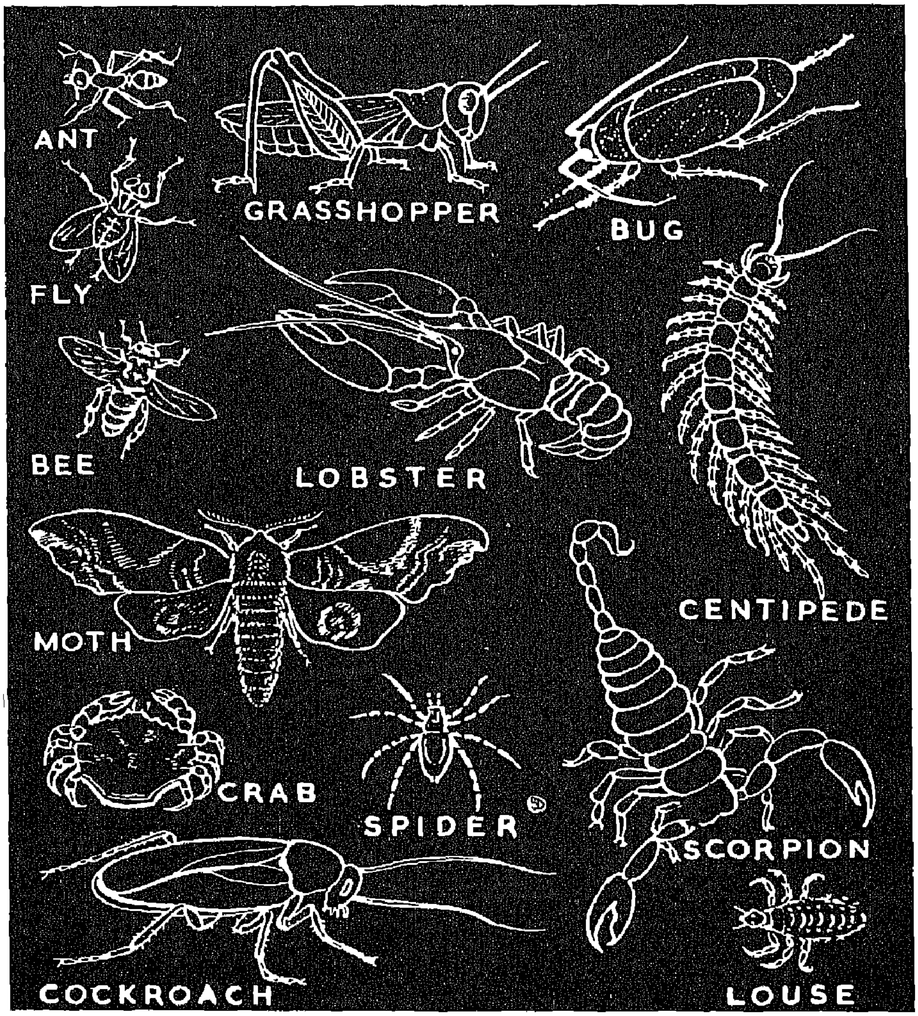

Fig. 9.9. Animals with jointed legs.

The arthropods have a hard outer covering but it is not like the shells of molluscs It has articulations which allow free movement of the legs and other parts of the body. The animals have segmented bodies (divided into distinct sections) and compound eyes having many lenses instead of just one. They have, therefore, a **mosaic vision.**

The Spiny-skinned Animals (Phylum Echinodermata)

The animals belonging here have a rough outer covering with projections or spines, hence the name **Echinodermata** (Gk. *echinos*=spine, *derma*=covering). They are built like a star or a wheel and have no head or tail, no left or right side The best known examples are starfish, sea urchin, brittle star, and sea cucumber (Fig. 9.10).

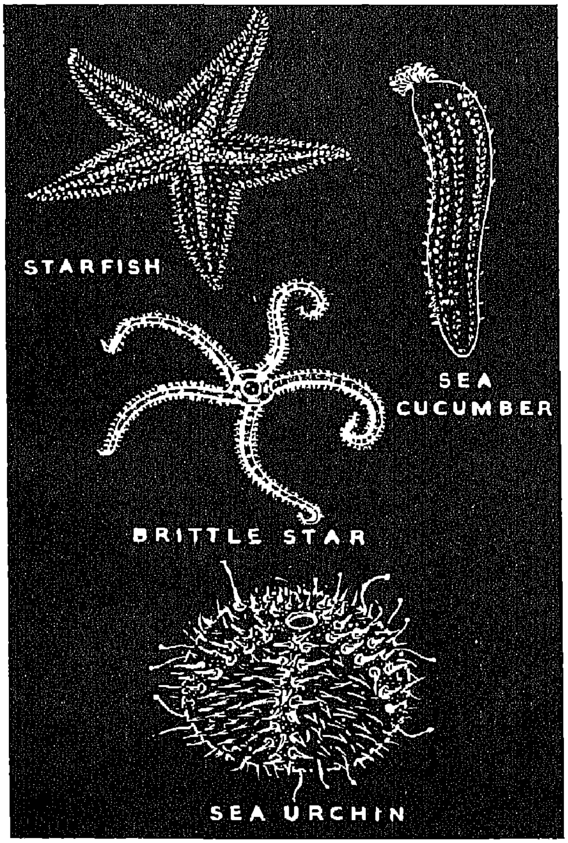

Fig. 9.10. The spiny-skinned animals.

ANIMALS WITH BACKBONES —THE VERTEBRATES

The animals that you have studied in the preceding phyla are all invertebrates, i.e., without backbones. The vertebrates, on the other hand, have a backbone made of several or many bone pieces called **vertebrae.** They all belong to one phylum, **Chordata** (Gk *chordē*=chord or string). This phylum also includes some other types of animals that have only a one-piece, non-bony rod or notochord in the place of a backbone. However, such animals are very uncommon, hence we shall read only about the animals with backbones—the vertebrates. The vertebrates are placed as a subphylum of chordata because in their early growth they too have a notochord which later helps to form the backbone.

Phylum Chordata (Subphylum Vertebrata)

Unlike the arthropods and the molluscs which have external skeletons, the vertebrates have their skeletons inside the body. The vertebrates have larger and better brains than the lower animals. Nearly all of them have two pairs of limbs, usually legs and arms. In fish, however, there are fins instead of limbs; in birds there are legs and wings; in whales there are flippers, and in the snakes there are no limbs at all. The

vertebrates are the animals with which you are most familiar—fishes, frogs, salamanders, lizards, snakes, birds, crocodiles, turtles, and all the hairy animals such as man, monkey, elephant, lion, cow, cat, dog, rabbit, and rat (Fig. 9.11).

The animal parade that you have seen illustrates one important fact that in spite of the obvious differences between different types of animals, there are some basic similarities which help us group them as we did. For the first time in 1857 the famous biologist

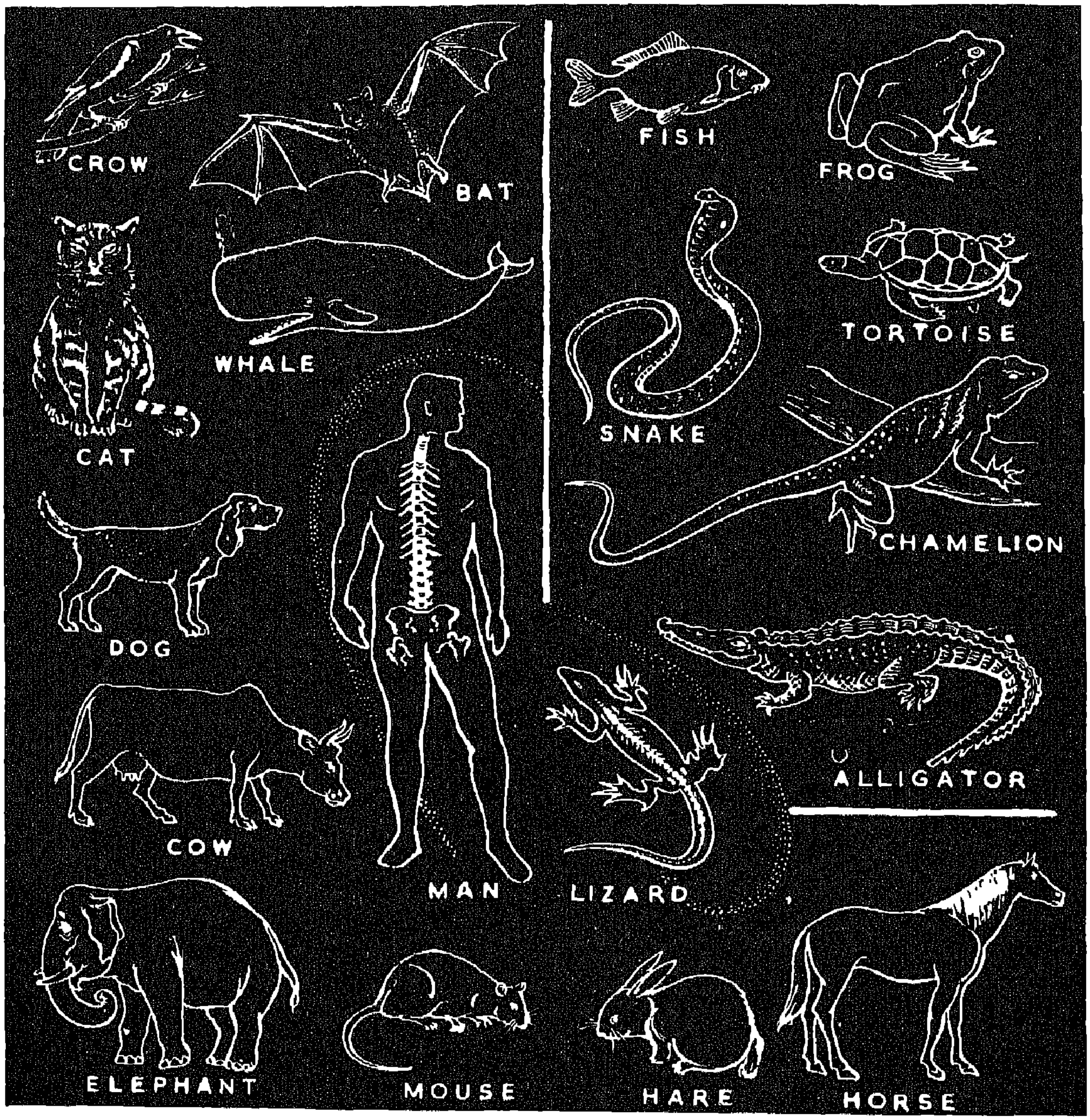

Fig. 9.11. The vertebrates. The vertebral column is shown in only two representatives.

Darwin suggested that all the animals (and plants too) are related to each other by descent, that they all had common ancestors from which they gradually evolved into their present forms.

Economic Importance of Animals

Animals have been constant companions of man from pre-historic times. Primitive man depended for at least a part of his food on wild animals, and he used their hides for protecting himself. As he became more civilized and hunting the wild animals was no longer convenient, he learned to domesticate a large number of animals. He has now the well-established practices of poultry and cattle breeding to supplement his food. In addition to these, various types of fish, lobsters and a variety of other animals are also used for food. The wool of sheep and fur from various animals protect him from cold. The feathers of birds are used for stuffing pillows. The hides of many animals yield leather and glue. Animal hairs are made into felt. Certain glands and internal organs are used for medicinal preparations. For instance, the oil from the liver of a fish called cod is universally used as a source of vitamins A and D. A large number of other useful products like honey, beeswax, shells, pearls, horns and sponges are derived from animals. Fisheries provide useful employment for thousands of people.

Many of our plants will not yield a good crop unless insects carry pollen from one flower to another. This is a relationship of mutual benefit, for the plants in return provide food to the pollinating insects.

The role of animals as 'guineapigs' in medical research has lately been very important. Before a new drug is released for use by human beings, it is first tested on certain animals like rats, rabbits and monkeys. Many sera are now-a-days prepared by infecting horses and cows with the germs of diseases. Even in these days of automobiles and space ships animals like donkey, camel and elephant remain a major means of transport in some parts of the world.

The earthworms have been regarded as Nature's ploughmen. These animals turn over large masses of soil and permit air and moisture to reach the roots of plants more freely. The aesthetic value of certain animals needs no exaggeration. The aquaria, shells of many molluscs, and the corals decorate the mantelpieces in many homes. Dogs, cats, parrots and even eagles are tamed as pets by many people (Fig. 9.12).

To these beneficial aspects of animals may also be added certain losses from which we suffer due to their activities. Insects and rodents eat away a large portion of our crops. Every now and then, in our country, we hear of locust swarms destroying fields after fields. Insects also attack stored foodgrains. Wherever facilities for storage are not adequate, these animals can rob us of as much as 50 per cent of the harvest. Certain animals like spiders, snakes and scorpions are mildly or highly poisonous. They cause much pain to man and his domesticated animals. Certain protozoans are parasitic and cause deadly diseases like malaria, dysentery, sleeping sickness and other diseases. The insects generally join hands with the parasites and serve to spread the disease from one victim to another. Some protozoans impart unpleasant odours to the water in which they grow.

Fig. 9.12. The association of man with other animals is very old indeed. The chart shows the roles animals play in our daily life. Courtesy of the Department of Botany, University of Delhi.

SUMMARY

More than a million types of animals have been described and named by biologists. They range in size from organisms that are visible only through the microscope to giant organisms such as the whales which may be over 30 metres in length.

Broadly speaking, animals can be grouped into two main subkingdoms—the invertebrates and the vertebrates. Depending upon their body plan they have been further classified into the following ten phyla:

Invertebrates

1. Phylum Protozoa—The first animals, mostly microscopic, aquatic and unicellular.
2. Phylum Porifera—Multicellular animals with skeletons of lime, cells of the body not much specialized.
3. Phylum Coelenterata—Sac-like animals with radial symmetry and having tentacles with stinging hairs.
4. Phylum Platyhelminthes—Flatworms.
5. Phylum Nematoda — Roundworms, mostly parasitic, body built on 'tube within a tube' plan (this is also true of the subsequent phyla).
6. Phylum Mollusca—Shell-bearing animals with unsegmented body lacking true appendages.
7. Phylum Annelida—Segmented worms, without jointed legs.
8. Phylum Arthropoda—Animals having jointed feet, segmented body, and an external skeleton.
9. Phylum Echinodermata—Spiny-skinned animals with deposition of calcium carbonate in their skin, entirely marine.

Vertebrates

10. Phylum Chordata—Animals with a backbone or a notochord.

Animals provide us with food, clothing, leather, medicines and several other products. Some animals, especially the insects, lead a life of mutual benefit with plants. Animals have also been of great service to humanity in medical investigations. Rodents and insects cause damage to stored foods. In some parts of the world animals are still used as beasts of burden.

QUESTIONS

1. Which are the simplest of the multicellular animals?

2. Mark the statements which distinguish coelenterates from other animals.
   (a) Presence of tentacles.
   (b) A large cavity with single opening.
   (c) The ability to move about freely.
   (d) Foul smell.
   (e) A tough outer skeleton.

3. How will you distinguish earthworms from roundworms?

4. What are the advantages of having an internal skeleton (as in the vertebrates) rather than an external skeleton (as in the arthropods and molluscs)?

5. At one time sponges were classified as plants. Why?

6. Snakes and worms look very much alike but are placed in different phyla. Why?

FURTHER READING

ANONYMOUS 1963. The Structure of Animals—Part I. *Understanding Science* Vol.5 No.51 pp 807-809.

ANONYMOUS 1962. Animals with no Hard Skeleton. *Understanding Science* Vol.1 No.6 pp.84-85.

BUCHSBAUM, R. 1948. *Animals Without Backbones.* University of Chicago Press, Chicago.

HANSON, E.D. 1961. *Animal Diversity.* Foundations of Modern Biology Series. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

HEGNER, R.W. 1935. *Parade of the Animal Kingdom.* The Macmillan Company, New York.

KROEBER, E., WOLFF, W.H. and WEAVER, R L. 1960. *Biology.* D.C. Heath and Company, Boston.

Contents of Sections That Follow

SECTION 2—THE DIVERSITY OF PLANT LIFE

SEED PLANTS

LOWER PLANTS

22. BRYOPHYTA
General characters—Life-history of *Riccia* and moss

23. PTERIDOPHYTA
General characters—Life-history of *Dryopteris*

SECTION 3—THE DIVERSITY OF ANIMAL LIFE

VERTEBRATES

24. FISHES AND FISH-LIKE ANIMALS
General characters with common Indian examples

25. AMPHIBIANS, THE FROGS AND THEIR RELATIVES
General characters and classification of amphibians—Detailed morphology and life-history of frog

26. REPTILES, THE SCALY FOUR-FOOTED VERTEBRATES
General characters and classification—The lizards—The snakes—Common poisonous and non-poisonous snakes of India—The crocodiles—The tortoises

27. BIRDS, THE FEATHERED VERTEBRATES
General introduction to birds—External characters of pigeon—Common Indian birds—Bird migration—Economic importance of birds

28. MAMMALS, THE HAIRY VERTEBRATES
General characters of mammals—A detailed study of the human body—The egg-laying, pouched and placental mammals with common Indian examples

INVERTEBRATES

29. PROTOZOA—THE SINGLE-CELLED ANIMALS
General characters—Structure and reproduction of *Amoeba*—Parasitic protozoa and their control

30. PORIFERA—THE PORE-BEARING ANIMALS—SPONGES
General characters—The structure of a simple sponge

31. COELENTERATA
General characters—The structure and mode of life of *Hydra*—Corals—Jellyfishes

32. PLATYHELMINTHES—THE FLAT WORMS
General characters—Life-history of liver fluke and tapeworm

33. NEMATHELMINTHES—THE ROUNDWORMS
General characters—Life history of the common roundworm, *Ascaris*—Helminths and their control

34. MOLLUSCA—THE SHELL-BEARING ANIMALS
General characters with common Indian examples

35. ARTHROPODA—THE JOINT-FOOTED ANIMALS
General characters—Crustacea, centipedes and millipedes, spiders and scorpions (general characters only)—General structure of cockroach—Useful and harmful insects

36. ECHINODERMATA—THE SPINY-SKINNED ANIMALS
General characters with examples

37. ANNELIDA—THE SEGMENTED WORMS
General characters of the earthworms and their allies

SECTION 4—PLANT AND ANIMAL PHYSIOLOGY

38. ON BEING ALIVE
Cell as physiological unit—Composition of protoplasm—Diffusion and osmosis—Provision of Energy—Enzymes

39. AUTOTROPHIC NUTRITION
Photosynthesis—Symbiosis—Saprophytism—Insectivory

40. HETEROTROPHIC NUTRITION
Nature of animal food—Digestion—Assimilation—Food chains

41 TRANSLOCATION
Distribution of food substances—Circulatory system in animals—Xylem and phloem in plants

42. RESPIRATION AND PROVISION OF ENERGY
Aerobic and anaerobic respiration—Ways of oxygen intake—Fermentation and its economic importance—Utilization of energy

43. EXCRETION
Excretory products—Organs and process of excretion

44. WATER ECONOMY
Necessity of water—Water economy in plants—Water economy in animals

45. GROWTH AND DEVELOPMENT
Definition and regions of growth—Measurement—Regulatory substances

46. RESPONSES AND CO-ORDINATION
Nervous system—Sense organs

SECTION 5—SELF-PERPETUATION OR REPRODUCTION

47. REPRODUCTION IN PLANTS
Definition—Historical—Bacteria—Algae—Fungi—Liverworts and mosses—Ferns—Seed plants

48. REPRODUCTION IN ANIMALS
Asexual reproduction—Sexual reproduction—Increasing care of young

SECTION 6—HEREDITY, EVOLUTION AND ADAPTATION

49. THE ORIGIN OF LIFE
Historical—Evolution of the earth—Formation of simple protein molecules—Origin of a virus—Beginning of real life—Conclusion

SECTION 7 —GENERAL